ERRORS OF ACCOMMODATION AND REFRACTION

CLARKE

THE ERRORS OF ACCOMMODATION AND REFRACTION OF THE EYE

THE ERRORS OF ACCOMMODATION AND REFRACTION OF THE EYE AND THEIR TREATMENT

A HANDBOOK FOR STUDENTS

BY

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PREFACE TO THE FOURTH EDITION

THE first edition of this work was published fifteen years ago based on lectures delivered at the Central London Ophthalmic Hospital and the Medical Graduates' College. I have not altered its character, which is essentially practical, all matter unnecessary for the busy practitioner or overburdened student being omitted.

The whole work has been thoroughly revised and brought up to date, many chapters having been rewritten.

The subject of Eyestrain still occupies the prominent place that is its due.

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ERRORS OF ACCOMMODATION

AND

REFRACTION OF THE EYE

CHAPTER I

REFRACTION—PRISMS—LENSES

LIGHT is propagated in straight lines which diverge from any luminous point in all directions, and these lines of direction are called "luminous rays." The propagation is produced by ether waves which are across the path of light. The velocity of light is, in round numbers, 186,000 miles per second, and is appreciably retarded in passing through a denser medium. Rays of light entering the eye coming from any luminous point at a greater distance than 6 metres may be assumed, for all practical purposes, to be parallel.

Light is absorbed, refracted, or reflected.

Refraction of Light.—A ray of light passing from a rarer into a denser transparent medium, if it be perpendicular to the surface, and the boundaries of the medium be parallel, will pass out of the denser medium in the same straight line (Fig. 1, L), the only effect upon it being a retardation. If the ray enter the denser medium other than perpendicularly, or if the boundaries of the medium be not parallel, the ray is bent or refracted.

A simple illustration will explain this.

Explanation of Refraction.—As ether waves are at right angles to the path of light, if a beam of light enter

a denser medium obliquely, one end of the wave will enter the denser medium before the other, and consequently be retarded earlier. Let A, B, C, D (Fig. 1), be a denser medium, with parallel boundaries, and N, O, P, Q, the beam of light.

The wave front will reach Q before it reaches R, and it will at once be retarded; and as it thus travels more slowly from Q to S than from P to R (which is outside the denser medium), the beam must be swung round so that it is bent or refracted on entering the denser medium.

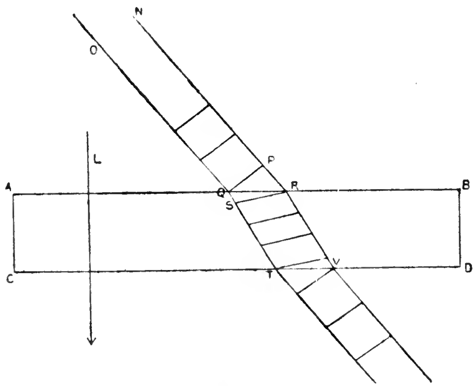

FIG. 1.

Across the denser medium the whole wave front is equally affected, so that the beam passes across in a straight line; and if the sides of the medium be parallel the converse happens, and it is again bent on passing out, the incident and the emergent rays being parallel.

Let this be applied to the case of, for example, a prism where the sides of the denser medium are not parallel. Suppose A, B, C (Fig. 2), to be a triangular strip of velvet pasted on a smooth board, and suppose *d* to be two small wheels connected by an axle in such a way that each wheel can turn independently of the other. Roll

the wheels up to the velvet triangle; the lower or right wheel will pass on to the velvet at *e* before the left wheel reaches it, and as the velvet will retard its progress, it will turn now more slowly than the left wheel, so that the pair of wheels will be slewed round towards the base of the triangle. When the left wheel enters on the velvet at *f*, its progress will be the same as that of the other wheel, and the pair of wheels will cross the velvet now in a straight line; when it reaches *m*, the left or upper wheel will leave the velvet earlier, and will consequently travel more rapidly, and will again swing the pair round, so

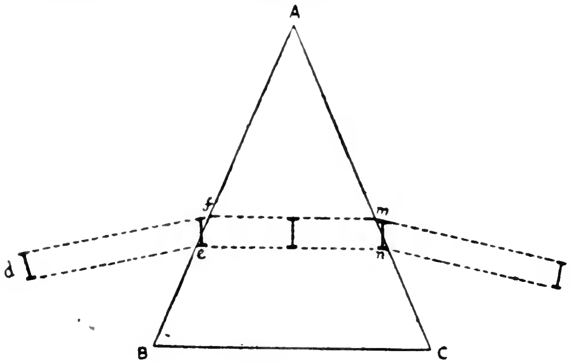

FIG. 2.

that in the transit across the triangle the pair of wheels have been bent towards the base.

It is in this manner that light behaves; in passing through a prism, it is bent or refracted towards the base.

A ray of light passing obliquely from a less dense into a denser transparent medium is refracted or bent *towards* the perpendicular, and when passing from a dense to a less dense medium is refracted *away* from the perpendicular.

Index of Refraction.—The index of refraction of a transparent substance is the number that denotes the

refractive power of such substance compared with air, which is taken as the unit 1. In Fig. 3, let A C be the incident ray meeting the horizontal surface of water at C, and forming with P P′, the perpendicular, an angle A C P; and let C B be the refracted ray in water bent towards the perpendicular, and forming the angle B C P′.

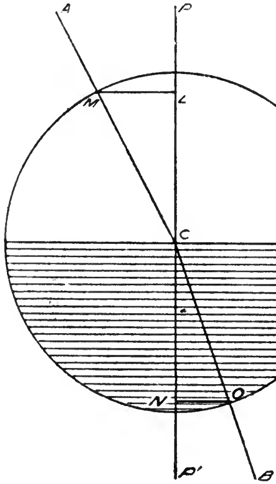

FIG. 3.

The sine L M is to the sine N O as 4 to 3, expressed as $\frac{4}{3}$, or 1·33, and this is the index of refraction of water.

The following are a few of the indices of refraction useful to the ophthalmologist:

Air	1·0
Water	1·33
Cornea	1·33
Aqueous humour	1·3379
Vitreous humour	1·3379
Crystalline lens	1·4
Crown glass	1·5

Prisms.—An ophthalmic prism is a wedge-shaped piece of glass having two of its sides, or plane surfaces, intersecting each other at the *apex*, and separated at the *base*, which is the thickest part of the prism.

We have already seen that a ray of light entering one of the sides of a prism is refracted or bent towards the base, and the amount of this refraction depends upon—

1. The strength of the prism.
2. The refractive index of the prism substance.
3. The position at which the light enters the prism.

The Strength of the Prism—*The Numbering of Prisms.*—The power of a prism to deflect or refract light depends on the size of the angle at the apex formed by

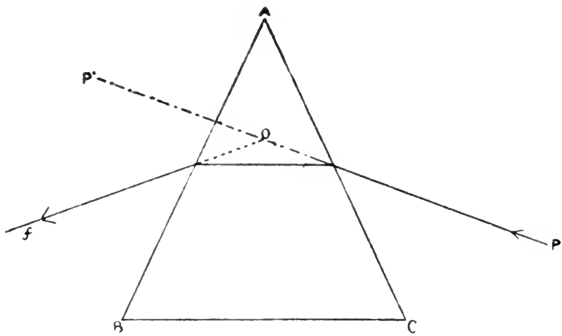

FIG. 4.

the two plane surfaces. This is called the *refracting angle,* and is written with the sign of a degree after the numeral—thus: 4°—which is scratched on the surface of the glass. This is the old, and even up to the present very general, method of numbering prisms.

Maddox has suggested the word "prismetry" to denote the numbering by the *deviating* angle.

The Deviating Angle of a Prism.—In Fig. 4, if a ray, P, enter the prism, instead of passing out at P′, it is refracted towards

the base B C, and away from the angle B A C, and is again bent towards the base on passing out, and emerges in the direction *f* (see page 3). The angle P′ *o f*, made by the backward prolongation of *f* and the forward prolongation of P, is the *angle of deviation*, and it is equal to about half the angle of refraction.

To indicate that the angle of deviation is implied, a small *d* is added; thus, prism 4° is approximately equal to prism 2° *d*.

Angle of Refraction.	Angle of Deviation.
1°	32′
5°	2° 42′
10°	5° 26′

As the metrical system is now universally adopted in ophthalmology, Prentice has suggested the numbering of prisms on the metrical plan, and the *prism dioptre* is the unit, designated by the sign Δ after the numeral.

A prism of the strength of 1 P.D. (1 Δ) is a prism that, at a distance of 1 metre, apparently displaces an object 1 centimetre. In Fig. 5, E, being the observer, sees O at O′ apparently displaced* 1 centimetre, the distance between O and the prism

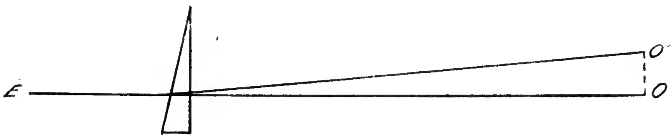

FIG. 5.

being 1 metre, and the prism 1 Δ; that is, the apparent displacement of an object looked at through a prism is 1 per cent. of the distance of the prism from the object, multiplied by the prism dioptre.

A prism 1 Δ apparently displaces an object 3 metres off, 3 centimetres, and a prism 3 Δ displaces an object 2 metres off, 6 centimetres, and so on.

Dennett has suggested the *centrad* as the unit for numbering prisms. The centrad is the hundredth part of a radian, a radian being the angle subtended at the centre of a circle by an arc, which is equal in length to the radius. A prism 1 centrad, designated 1 ∇, deviates a ray of light one-hundredth part of the arc of the radian.

It is interesting to note that the centrad has a relative value to the metre angle, in that half the number of centimetres between the pupils indicates the number of centrads in the metre angle.

This method is not much used, although probably the most scientific.

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* Note that the apparent displacement of an object viewed through a prism is always towards *the apex*.

All three methods of numbering prisms are practically identical for weak prisms, and, as it is only weak prisms that an ophthalmologist can use, it matters little what method he adopts.

TABLE SHOWING THE EQUIVALENCE OF CENTRADS, PRISM DIOPTRES, AND REFRACTING ANGLE, OF THE SIX WEAKEST PRISMS. (INDEX OF REFRACTION, 1·54.)

Centrad.	Prism Dioptre.	Refracting Angle.
1	1	1°
2	2·0001	2·12°
3	3·0013	3·18°
4	4·0028	4·23°
5	5·0045	5·28°
6	6·0063	6·32°

The minimum of deviation occurs when the incident ray crosses the prism parallel to its base; but in thin prisms—and it is thin prisms only that the ophthalmologist uses—this has no practical importance. Hence we can neglect the position of the incident ray.

The Uses of Prisms.—

1. To remove diplopia.
2. To ease the muscles, and so prevent muscle strain and subsequent diplopia (see page 176).
3. To exercise *weak* muscles (see page 182).
4. To test the strength of the external ocular muscles.
5. To detect malingerers (see page 183).

In trial cases the prisms are usually cut circular, so that they can be used in a trial frame; the exact position of the base of the prism is usually marked by a line on the glass at right angles to the base.

Rotating Prisms.—If two prisms of equal strength be placed in apposition in such a manner that the base of the one is in contact with the apex of the other, they neutralize each other, and if we rotate them in opposite directions we obtain the effect of an increasingly strong prism.

Risley's Rotary Prism (Fig. 6) is made on this principle. If we place it in one side of a trial frame, both eyes being used, start from zero and gradually turn the button, we

can ascertain the strongest prism the eyes can stand without having diplopia, or, if we are dealing with a case of diplopia, we can ascertain the weakest prism that will procure "fusion" vision.

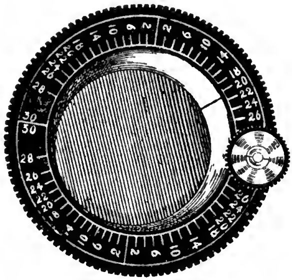


FIG. 6.

The numbers on the frame indicate the refracting angle in degrees. The instrument can give a total prismatic power of 30°.

Prisms form no images and have no foci.

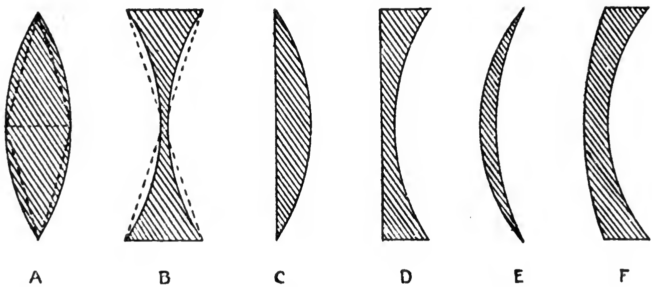


FIG. 7.

Lenses.—If two prisms are placed with their bases in contact, we have roughly a bi-convex lens (Fig. 7, A), and rays of light passing through it are bent towards the base of the prisms—*i.e.*, the centre of the lens; in other words, they converge. If the prisms have their

apices in contact, we have a bi-concave lens (Fig. 7, B), and the rays are bent towards the bases—*i.e.*, outwards—and diverge.

Spherical Lenses.—Besides the bi-convex (Fig. 7, A) and bi-concave lenses (B), there are plano-convex (C),

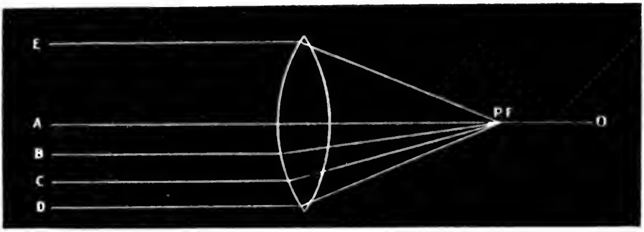


FIG. 8.

plano-concave (D), converging concavo-convex or converging meniscus (E), and diverging concavo-convex or diverging meniscus (F). Rays of light passing obliquely through any of these forms of lenses are refracted or bent towards the *thickest* part of the lens.

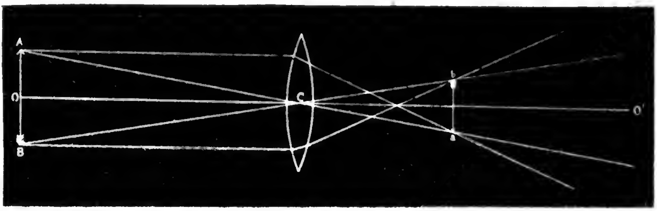


FIG. 9.

The principal axis is a line drawn through the optical centre at right angles to the lens (Fig. 8, A O), and rays passing through this are not refracted; all other lines passing through the optical centre not at right angles to the lens are called "secondary axes" (Fig. 9, A *a*).

Rays passing along the secondary axes are refracted,

but as the emergent and the incident rays are in the same direction, and the refraction in low-power lenses is very slight, the refraction can be ignored, and the rays assumed to pass along in a straight line.

Convex Lenses.—Parallel rays passing through a convex lens unite on the opposite side of the lens at a point called the "principal focus" (Fig. 8, P F).

At the principal focus an inverted real image of the object is formed. Let A B (Fig. 9) be an object at some considerable distance from the lens. Any ray passing from the point A through the optical centre of the lens C will be unrefracted (*vide supra*), and the image of A will be somewhere on this line on the other side of the lens

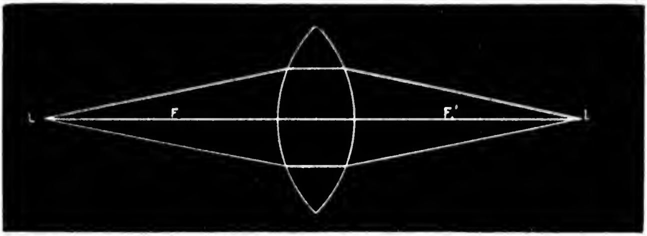


FIG. 10.

—let it be at *a*; all other rays passing from A will be refracted on passing through the lens, and will focus at *a*. In the same manner an image of B is formed at *b*, and all other points between A and B will form an image between *a* and *b*, so that we get an inverted image *a b* of A B formed at the principal focus of the lens.

The distance between the principal focus and the optical centre is called the "principal focal distance"; it is positive, and convex lenses are known by the plus sign: +.

Rays passing from the principal focus (P F) through the lens emerge as parallel rays on the opposite side (Fig. 8).

Divergent rays from a point L (Fig. 10) beyond the principal focus F meet at a point *l* beyond the principal

focus F′ on the other side of the lens. If the point L is twice the focal distance of the lens, then l will be at the same distance on the other side. These two points are called "conjugate foci," and are interchangeable; that is, the object may be at L or l, and the image is respectively at l or L.

If a luminous point be between the convex lens and the principal focus, the rays will still be divergent when they leave the lens on the opposite side, and consequently no real image is formed; but a magnified virtual image is formed beyond the principal focus on the same side, at a point called the "virtual focus," and this virtual image

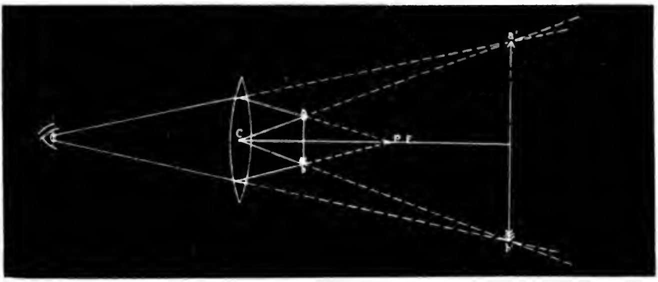


FIG. 11.

is seen by an observer on the opposite side of the lens, the light from the points *a* and *b* appearing to the observer to come from *a′* and *b′* (Fig. 11).

Concave Lenses.—Parallel rays passing through a concave lens diverge, and consequently never come to a focus; but these divergent rays, if prolonged backwards, will meet at a point F (Fig. 12).

This point is the (virtual) principal focus of a concave lens.

If an object be placed beyond the principal focus of a concave lens, an observer on the opposite side of the lens will see a virtual, erect, smaller image on the same side as the object; thus, rays from *a* and *b* will appear to

come from a' and b', and the object a b is seen as a' b' (Fig. 13). As concave lenses have a negative focal distance, they are denoted by the minus sign: —.

Cylindrical Lenses.—In addition to spherical lenses cylindrical lenses are required—these are lenses cut out

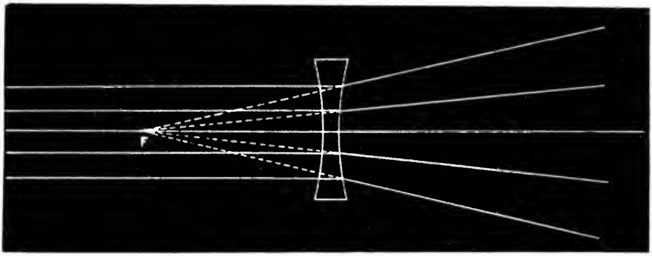


FIG. 12.

of a cylinder; convex cylinders are cut from a solid cylinder (Fig. 14, *a*), concave cylinders from a hollow cylinder (Fig. 14, *b*), which may be regarded as the mould of convex cylinders. Cylinders have the property of not

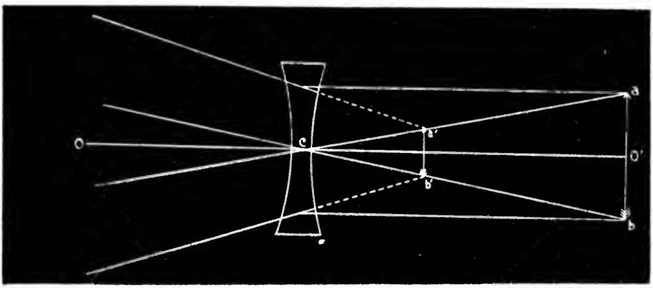


FIG. 13.

refracting any rays that pass along their axis, but rays passing at right angles to the axis undergo the maximum refraction corresponding to the strength of the lens. According to the angle at which the rays impinge upon the lens, they undergo more or less refraction, as this

angle is further away from, or nearer to, the axis of the cylinder. A cylinder has no one focal point, but a line of foci parallel to its axis.

Cylindrical lenses are employed to correct regular astigmatism.

The axis of a cylindrical test lens is marked by a small line on the glass, or by making the sides of the lens, parallel to the axis, opaque.

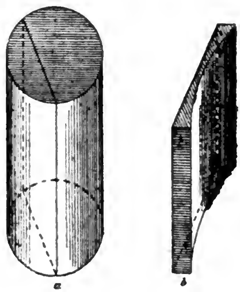


FIG. 14.

Numeration of Lenses.—The lens whose focal distance is 1 metre is taken as a unit, and its refractive power is called one Dioptry or Dioptre ("D"). A lens of twice the power of this—viz., 2 D—has a focal distance of $\frac{100}{2}$; *i.e.*, 50 cms.; a lens of half the power—viz., ·5 D—has a focal length of 2 metres, and so on. The focal distance of a lens nD $= \frac{100 \text{ cms.}}{n}$

Under the old system, a lens whose focal distance was 1 inch was taken as the unit, and a lens whose focal length was 10 inches was called $\frac{1}{10}$, 30 inches $\frac{1}{30}$, and so on. The great disadvantage of this method of numeration was the inability to make it international, because the inch is not an international measure.

To convert the old numeration into the new, divide the denominator into 40; thus, lens $\frac{1}{5}$ is $\frac{40}{5}$=8 D, and *vice*

versa. To convert dioptres into inches, divide the dioptre into 40, and the result is the focal length in inches; thus, $4\ \text{D} = \frac{40}{4} = 10$ inches focal length, expressed as $\frac{1}{10}$.

The following table shows at a glance the approximate equivalent of the old and new numeration:

Dioptres.		Inches.	Dioptres.		Inches.
·12	....	320	4	....	10
0·25	....	160	4·50	....	9
0·37	....	107	5	....	8
0·50	....	80	5·50	....	7
0·62	....	64	6	....	6½
0·75	....	53	7	....	6
0·87	....	46	8	....	5
1	....	40	9	....	4½
1·25	....	32	10	....	4
1·50	....	26½	11	....	3½
1·75	....	22½	12	....	3⅓
2	....	20	13	....	3
2·25	....	17½	14	....	2¾
2·50	....	16	15	....	2⅔
2·75	....	14	16	....	2½
3	....	13	17	....	2⅓
3·50	....	11	18	....	2¼
			20	....	2

Testing Lenses.—It is important to be able to test a lens and find out its optical value. Instead of going through the process of finding its principal focus, and measuring the distance of this from the lens centre, we place in front of it lenses of the opposite value; thus, if we wish to find the strength of a convex glass, we neutralize it with concave glasses.

A finer test is to employ the parallactic movement. If we look at a distant object through a convex glass and move the glass, the object appears to move in the opposite direction; if we use a concave glass, the object appears to move in the same direction. So long as there is any movement we must place up concave or convex glasses, according as the displacement of the object is "against" or "with."

In testing cylinders we have to ascertain not only the value, but also the direction of the axis.

When cylinders are moved in front of the eye in the direction of the axis, objects looked at through them are *not* displaced; but the smallest rotation of the cylinder causes displacement, which reaches its maximum when the movement of the cylinder is in the direction at right angles to its axis. In this position neutralize with cylindrical lenses of the opposite value, bearing in mind that displacement takes place "against" the movement so long as a convex lens predominates, and "with" the movement so long as a concave one predominates. The axes of the two lenses must coincide.

When testing a sphero-cylindrical glass, the spherical lens should be first neutralized.

A great saving of time is effected by testing glasses with the *Geneva lens measure* and the *Maddox cylinder-axis finder.*

The Combination of Lenses—*Convex Spherical Lenses.*—The ordinary way for such lenses to be ground is to work half the power needed on each surface; thus, when +4* is required, each surface of the lens is made equal to +2, as if two plano-convex glasses of +2 had their plane surfaces cemented together.

Another method of working a convex lens is to grind the surface away from the eye as a convex lens of higher power than is required, and the other surface concave of such a strength as to reduce the convex surface to the desired amount. Thus, when +4 is ordered, one surface can be made +7 and the other surface −3, or one surface can be +6 and the other −2. Such lenses are called "periscopic"; they enlarge the field of distant vision, as the eye in all its movements is at the same distance from the surface of the glass, but their chief advantage is in enabling the glasses to be placed nearer the eye without being touched by the lashes.

* In the following pages, the numeration of lenses will always be in dioptres, and "D" after the numeral will be generally omitted.

Concave Spherical Lenses.—These are usually made with half the strength required, on each surface. A certain amount of periscopic effect may be obtained by grinding the surface nearer the eye more concave, and reducing the other: thus, -8 may be, and usually is, made -4 on each surface, or the surface nearer the eye may be made -6 and the other -2; or the lens may be ground as a diverging meniscus (Fig. 7, F); thus, if -3 is required, the surface next the eye is ground as -5, and the other surface as $+2$.

Cylindrical Lenses.—When a cylinder only is prescribed, it is ground on one surface, the other surface remaining plane. When combined with a spherical lens, it is usual to grind the sphere on one surface, and the cylinder on the other. When a convex sphere and cylinder are required, the periscopic effect can be produced by grinding a concave cylinder on the surface nearer the eye, and increasing the spherical strength by the amount of the cylinder. Thus, supposing $+2$ cyl. axis vert. $\bigcirc$ $+3$ sph. is needed, it may be ordered thus:

-2 cyl. axis horizontal $\bigcirc$ $+5$ sph.

In ordering glasses for mixed astigmatism (see page 137), the periscopic effect is produced by combining a convex cylinder with a concave sphere, and mounting the latter next the eye.

As it is very important to divide the strength of the lens between the two surfaces when dealing with high powers, a cylinder, if also required in such a case, must be worked on one of the spherical surfaces. These lenses are called *Toric* lenses, and any combination of spherical lens (·25 to 18), with cylindrical lens (from ·25 to 3) can be supplied. Thus, if -14 sph. $\bigcirc$ -2 cyl. axis horizontal is required, one surface is made -7, and the other -7 sph. $\bigcirc$ -2 cyl. These toric lenses are very useful in high myopia, and also in aphakia.

Bi-Focal Lenses (see Presbyopia, page 151).—Where

different lenses are required for distance and reading, bi-focal lenses are generally prescribed.

The earliest forms of these glasses were straight split bi-focals, also called "Franklin" glasses, the lenses being two separate lenses divided horizontally and in the middle. Against the many disadvantages of this form of bi-focal was the one advantage that the lower lens could be slanted and made more or less parallel with the book or paper that was being read.

An improvement on these "split" bi-focals consisted having the reading addition cemented on by Canada alsam, either as in Fig. 15 or as a small round wafer.

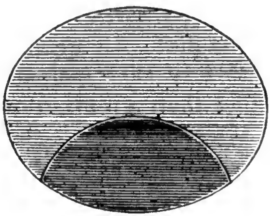


FIG. 15.

The disadvantage of both these forms was chiefly manifested by the dividing line between the lenses being visible and constantly causing annoyance to the wearer. Another disadvantage of the cemented bi-focals is the tendency of the balsam to dry or crystallize.

The next improvement did away with the visible line, and these bi-focals are called "invisible bi-focals." They are of two kinds, one the so-called "Kryptok," where a concavity is ground in the lower part of the distance glass, and the reading glass, of a higher refractive index, is fused into it; the other, the final perfected form of invisible bi-focals is the "Luxe," which consists of one glass only. The glass is made from a solid piece of crown glass with the two lenses ground invisibly on its surface. The chief advantage of these "Luxe"

bi-focals is that the centring of both portions is more under control, and there is no chromatic aberration, which is so often present in the fused form.

Spherical Aberration.—In most lenses the rays passing through the peripheral part of the lens do not focus at the same spot as those which pass through the central portion. In convex lenses, when the peripheral rays focus in front of the central rays, the *aberration* is spoken of as *positive;* and when the peripheral rays focus behind the central, as *negative.* The crystalline lens suffers from spherical aberration, but it is more or less hidden by the contraction of the pupil. During mydriasis this aberration may interfere considerably with vision, but may be corrected by placing in the trial frame an opaque disc with a central circular opening. If the refraction is being estimated, this opening should not be smaller than 4 mm. in diameter.

CHAPTER II

OPTICAL PROPERTIES OF THE NORMAL EYE

THE eye is constructed in the form of a photographic camera. As in the camera, there is a closed darkened box open in front, where there is an arrangement of lenses to focus an object on the back, at which spot there is the apparatus for receiving the perfectly-formed image: the plate in the camera, the retina in the eye.

As in the camera, there are two conditions which must exist in the eye: firstly, the media must be transparent; and, secondly, the focusing must be so arranged that a perfect image of the external object is formed on the retina—*i.e.*, the principal focus of the eye must coincide with the retina.

All deviations from this latter condition are called errors of refraction and accommodation.

The Refraction of the Normal Eye at Rest—i.e., in the Absence of any Effort of the Accommodation— *Dioptric Apparatus of the Eye.*—The simplest form of a dioptric apparatus is when two media of different refractive power are separated by a spherical surface.

Such a system is represented by Fig. 16, where *x y z* is a spherical surface separating a less refractive medium on the left from a more refractive medium on the right. The line O A passing perpendicularly to the surface of the sphere and through its centre at N is called the "optic axis."

All rays passing normally to the surface, such as R N and S N, like the optic axis, pass through N, and undergo

no refraction; N, the centre of the sphere, is called the "nodal point."

The point *y* where the optic axis cuts the sphere is called the "principal point."

Rays *c*, *d*, parallel to the optic axis in the less dense medium, unite somewhere on the optic axis at the point F, called the "posterior principal focus."

On the optic axis, in the less dense medium, there is another point (F′), called the "anterior principal focus," whence divergent rays passing into the denser medium are refracted, and become parallel to the optic axis as at *z f*.

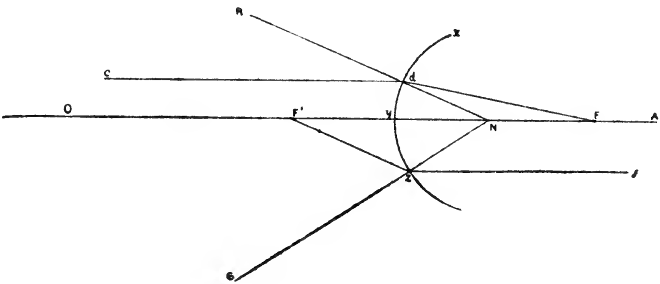


FIG. 16.

These four points—the principal point, nodal point, and anterior and posterior principal focus—are called "cardinal points" of the system.

In the eye the system is much more complicated. A ray of light passing into the eye meets the following surfaces and media in the order named: Anterior surface of the cornea, substance of the cornea, posterior surface of the cornea, aqueous, anterior surface of the lens, substance of the lens, posterior surface of the lens, and vitreous. Thus there are four surfaces and, if we include the air, four media. As the anterior and posterior surfaces of the cornea are parallel, we may neglect the substance of the cornea, and consider the two surfaces as one. Again, as the indices of refraction of the aqueous

and vitreous are identical (see page 4), we may assume them to be one medium. In this manner the eye is reduced to three surfaces and three media.

These three surfaces—the cornea, and the anterior and posterior surfaces of the lens—are symmetrically centred round the optic axis of the whole system, which may now be reduced to a compound system, consisting of the cornea and a bi-convex lens; we find the principal points p' p'' (Fig. 17) and the nodal points n' n'' of the cornea and lens; and, finally, take the mean of these two points,

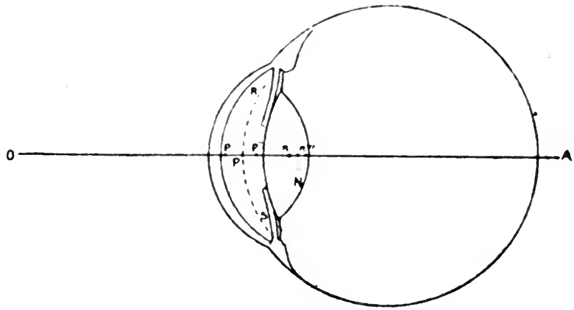


FIG. 17.

and get P the principal focus and N the nodal point. Such an eye is known as the "reduced eye," and was suggested by Listing.

The positions of the cardinal points of the reduced eye are—

Principal point, in the aqueous, 2·3448 mm. behind the anterior surface of the cornea.

Nodal point, in the lens, ·4764 mm. from its posterior surface, and about 15 mm. from the retina.

Posterior principal focus, 22·819 mm. behind the anterior surface of the cornea—*i.e.*, on the retina of the normal eye. (This is the length of the standard eye.)

Anterior principal focus, 12·8 mm. in front of the anterior surface of the cornea.

The principal plane R P S (Fig. 18) is where the one surface of this reduced system passes through the principal point P which is considered the centre of refraction of the eye.

The optic axis (O A) is an imaginary line passing through the centre of the cornea and the nodal point, and meeting the retina a little above and to the nasal side of the fovea.

The nodal point corresponds to the optical centre, and, as we have already seen, all rays passing through it are unrefracted.

We can now ascertain how an image is formed on the retina.

Let X Y (Fig. 18) be an object in front of the eye; each

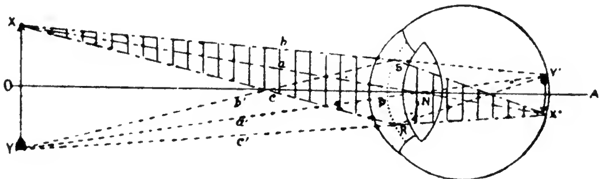


FIG. 18.

point of this sends out a pencil of divergent rays, and all those which pass into the eye, by the dioptric system, are made to converge into a point on the retina.

Each pencil of rays from the point X has a principal ray X *a*, which is normal to the surface, and, passing straight through the nodal point N without refraction, impinges on the retina at X′. The other rays from X are increasingly divergent, and are represented by X *b*, X *c*; they undergo refraction, and converge together at some point on the principal ray, which in the normal eye will be at X′. In like manner we can trace the rays from the other extreme point Y, which forms an image at Y′, and so for all the other points.

In tracing the formation of an image on the retina,

we can ignore all the rays from a point of the object, except the principal ray, which we trace through the nodal point; and by tracing all the luminous points from an object through the nodal point, we obtain in the normal eye an inverted image of the object on the retina.

The nearer the object is to the eye, the larger will be its image, and *vice versa.* **The size of the retinal image** is therefore directly proportional to the distance of the object from the eye.

It is sometimes important for the oculist to determine the size of the retinal image of an object in order to dis-

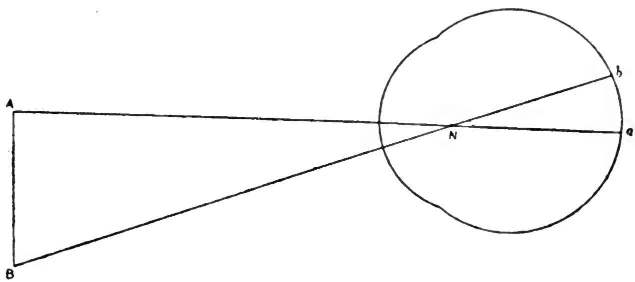


FIG. 19.

cover the size of a diseased area; this can be estimated if the size of the object and its distance from the eye be known.

The triangles A N B and *a* N *b* (Fig. 19) are similar, hence *a b* : A B : : *a* N : A N—that is, the size of the area on the retina is to the size of the object as the distance from the nodal point to the retina is to the distance of the nodal point from the object. Let the latter be 10 metres and the size of the object 1 metre; we know that the distance *a* N is 15 mm.—consequently:

$$a\,b : 1{,}000 : : 15 : 10{,}000;$$

$$\therefore\ a\,b = \frac{15{,}000}{10{,}000} = 1{\cdot}5 \text{ mm.}$$

The perfect type of eye is that in which the retina coincides with the posterior principal focus, and is called

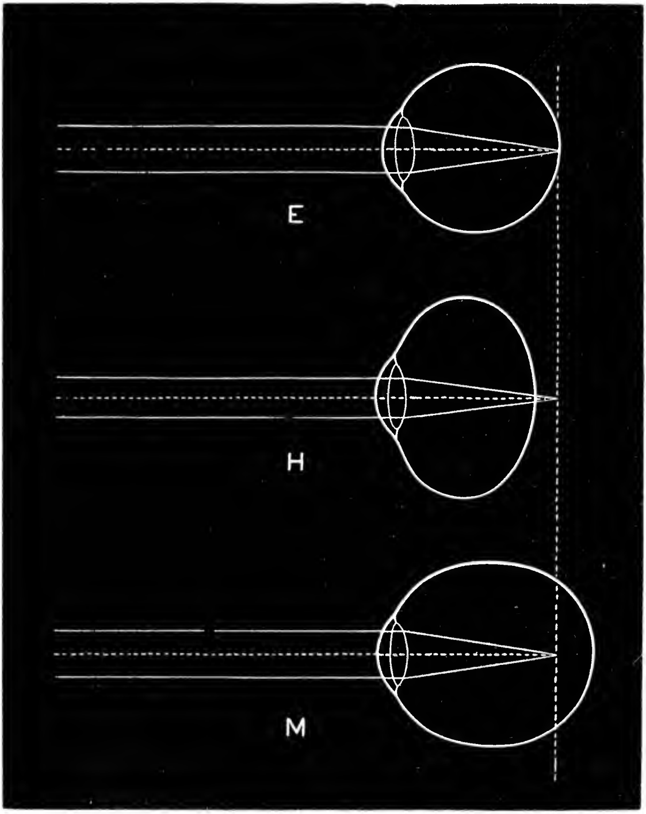


FIG. 20.

Showing parallel rays focused on the retina in emmetropia (E), behind the retina in hyperopia (H), and in front of the retina in myopia (M).

the "emmetropic" eye (E, Fig. 20), and any deviation from this is called **ametropia.**

The following table gives an idea of the relative frequency of the different forms of ametropia:

2500 individuals whose sight after correction was normal and who had no disease of the eyes.	(1) Same refraction in both eyes (657)	(a) Emmetropia (see Presbyopia below)	9
		(b) Hypermetropia	63
		(c) Myopia	22
		(d) Astigmatism— Hypermetropic	438
		Myopic	113
		Mixed	12
	(2) Refraction different in the two eyes (Anisometropia)		1843
			2500

5000 eyes (as above)—	
Emmetropia	56
Hypermetropia	425
Myopia	216
Astigmatism	4303
	5000

Of the 2500 individuals, 961 were presbyopic, and only 9 of these were emmetropic.

If the posterior principal focus is beyond the retina, the eye is too short, and parallel rays, when they meet the retina, have not yet come to a focus, and only convergent rays come to a focus. This is called "hyperopia" (H, Fig. 20).

If the principal focus is in front of the retina, the eye is too long; parallel rays focus in front of the retina, and only divergent rays focus on the retina. This condition is called "myopia" (M, Fig. 20).

The Visual Angle and Visual Acuity.—Rays of light, proceeding from the two extremes of an object into the eye, meet at the nodal point N (Fig. 21) before crossing and forming the inverted image on the retina, and the angle included at N is called the "visual angle." A N B is the visual angle of the object A B (Fig. 21).

The size of the visual angle depends on the size of the object and its distance from the eye; thus, A′ B′, which

is the same size as A B, subtends a larger angle, and the image is larger; and, again, A″ B″ subtending the same visual angle as A B would appear to be the same size, whereas it is much smaller. Fortunately, we do not gain our estimation of the size of objects by the visual angle alone; experience and comparisons with other objects of known size are brought into play, and enable us to correct any erroneous judgment.

The smallest visual angle in which the standard eye can recognize an object is an angle of one minute, so that two points of light, such as two stars, separated by an angular interval of less than one minute would appear on the retina as only one point.

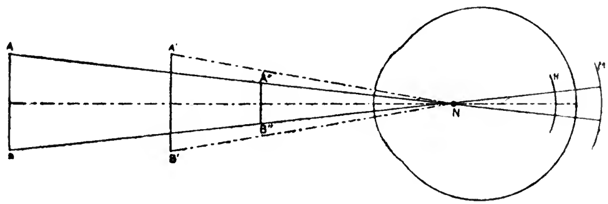


FIG. 21.

Test Types.—It is most important to have a standard measure for acuteness of vision, and Snellen has arranged test types on such a plan that each letter is made up of several parts, each of such a size that it subtends an angle of one minute vertically and horizontally, the whole letter subtending an angle of five minutes vertically and horizontally when read at the standard distance.

Thus, in Fig. 22, the F is made out of twenty-five squares, each subtending an angle of one minute (the whole letter subtending an angle of five minutes) when read by the normal eye at 12 metres; and the L, which is constructed on the same plan, subtends the same angle when read by the normal eye at 6 metres.

The numbers of the different-sized letters in Snellen's types represent the distance in metres at which the

standard eye can read them; in other words, at that distance they subtend an angle of five minutes. For instance, the largest type, D = 60 (see type at end of book), can be read by the normal eye at 60 metres, and it subtends the same angle as the type D = 24 read at 24 metres, and D = 6 read at 6 metres. The acuteness of vision is represented by a fraction which has for its numerator the distance in metres at which the type is read, and for its denominator the distance at which it ought to be read. The line D = 6 means that this type can be read by the normal eye at 6 metres, and if the patient under examination can read it at 6 metres, the fraction is $\frac{6}{6}$—that is, normal vision. If the patient cannot see a smaller type than D = 12 at 6 metres, his

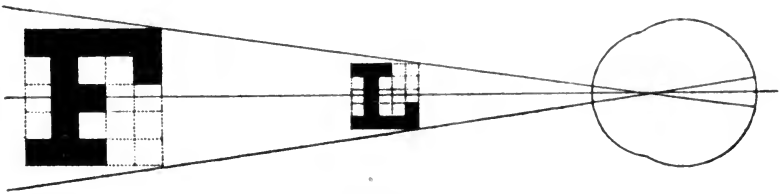


FIG. 22.

vision = $\frac{6}{12}$; if D = 60 is the only letter that can be read at 6 metres, his vision = $\frac{6}{60}$—*i.e.*, one-tenth of the normal. If D = 60 cannot be read at 6 metres, the patient must be made to approach the type; if he can just read this letter at 2 metres, his vision is $\frac{2}{60}$; he has only one-thirtieth of normal vision. Although $\frac{6}{6}$ is the standard of normal acuteness of vision, many eyes can see better—viz., $\frac{6}{5}$, or even $\frac{6}{4}$; *i.e.*, such eyes can read at 6 metres type that the standard eye cannot read at a greater distance than 5 and 4 metres respectively.

If the visual acuity is so lowered that the patient cannot see any letter at any distance, it can be measured by finding whether he can count fingers, and if so, at what distance, and failing this, by finding whether he

can distinguish between black and white. If vision is even worse than this, we take him to the light and pass the hand in front of the eye—*i.e.*, between the eye and the light; if movement is recognized, we find out whether he can distinguish the *direction* of the movement.

Finally, if he fails at all these tests, he should be taken into the dark room, and a strong beam of light should be directed on to the eye; if this is not perceived, vision = 0; if it is perceived, we ascertain whether he has good projection, by reflecting the light on to the eye from different positions, and ascertaining whether he can tell whence the light is coming.

Type for Near Vision.—As the "Schrift-scalen" of Professor Jaeger represent no standard, this type is being superseded by Snellen's, which is on the same principle as his distant type, the figure over the type signifying the greatest distance at which the normal eye can read it, and, of course, subtending an angle of five minutes at that distance. The sizes range from D = ·5 to D = 4 (see type at end of book). J ·2 (Jaeger) is the equivalent of D ·5 (Snellen).

D=0,5.

As to my boat, it was a very good one, and that he saw, and told me he would buy it of me for the ship's use and asked me what I would have for it.

D=0,6.

In this distress the mate of our vessel lays hold of the boat, and with the help of the rest of the men, they got her slung over the ship's side.

D=0,8.

A little after noon I found the sea very calm, and the tide ebbed so far out, that I could come within a quarter of a mile of the ship;

D=1.

In search of a place proper for this, I found a little plain on the side of a rising hill, whose front towards this little plain was steep as a house side.

D=1,25.

Then I took the pieces of cable which I had cut in the ship, and laid them in rows one upon another, within the circle between these two rows of stakes.

D=1,5.

When I had done this, I began to work my way into the rock, and bringing all the earth and stones, that I dug down, out through my tent.

D=2,25.

For in this way you may always damp our ardour.

D=3.

I saw no one there.

D=4.

For the ensuing

D=60 (200)

A

D=36 (120)

CV

D=24 (80)

L A V

D=18 (60)

R T B

D=12 (40)

D F O E

D=9 (30)

C L Z T O

D=6 (20)

L T R F P

D=5 (16)

A P O R F D

CHAPTER III

ACCOMMODATION

When, with one eye closed, the other eye focuses a needle a metre from the eye, another needle placed half a metre from the eye will appear blurred.

If A (Fig. 23) be the first needle, a clear image is formed by the exact focusing of it on the retina at A′,

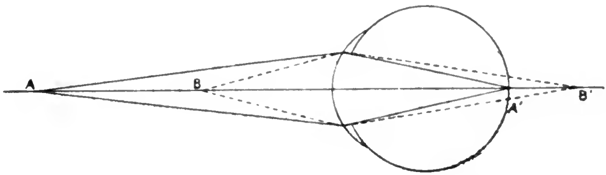


Fig. 23.

Fig. 24.

while the image of B will be focused beyond the retina at B′, the rays from B impinging on the retina in the form of a collection of diffusion circles.

On the other hand, if the needle B be focused on the retina—*i.e.*, if its image be clearly seen—the needle A

will appear hazy or out of focus, because its image is focused in front of the retina, and, after crossing, the rays impinge on the retina as diffusion circles.

Diffusion Circles.—Two points of light, if near one another and out of focus, appear as two diffusion circles overlapping each other if near enough (Fig. 24, A).

As a line in focus may be considered to be an infinite number of points of light in focus, so a line out of focus consists of a series of overlapping diffusion circles (Fig. 24, B) which makes the line appear as a broad band, as Fig. 24, C. The further the rays focus from the retina, the larger will be the diffusion circles. In Fig. 25 both A and B are "out of focus," but B is more so than A, and consequently the diffusion circles formed by B

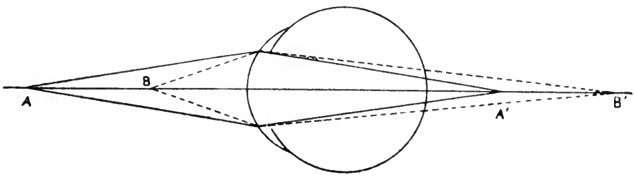


FIG. 25.

occupy a larger area; and, again, the larger the pupil the larger the area of diffusion circles, because as the pupil contracts it cuts off the outside rays.

The alteration of the eye by its focusing mechanism is called **accommodation.** The photographer focuses by lengthening or shortening the distance between the back of the camera and the lens, but he could also focus by adding a convex or concave lens to that he is already using.

It is in this latter way that the eye focuses; the eye cannot lengthen, but the lens can become more convex, which has the same result as adding a convex lens.

In the normal standard eye, parallel rays, coming from a distance beyond 6 metres, are focused on the retina when the eye is at rest—*i.e.*, when the apparatus of

accommodation is not being used; but when the eye wishes to see clearly any object nearer than 6 metres, the lens must become more convex.

After looking at the needle A, when we look at needle B and obtain a clear image, we are distinctly conscious of an effort, and the nearer we approach B to the eye the greater is the effort, till we reach a spot near the eye when no effort will produce a clear image, because the rays from the needle are too divergent to be focused on the retina. The nearest point to the eye at which the object is recognized as a perfectly clear image is called the near point "P." After looking at the needle close to the eye, and again looking at the distant needle, we are conscious of a relaxation of our efforts.

How do we know that this focusing or accommodation is caused by an increased convexity of the lens?

The Mechanism of Accommodation.—If we take a patient into the dark room and hold a candle in front o the eye a little to one side, we shall see three images oı this candle in the eye. One, the brightest, is upright, the reflection coming from the anterior surface of the cornea; the second, duller, is also upright, and is the reflection from the anterior surface of the lens; and the third is inverted, duller, and smaller, and is from the posterior surface of the lens. The patient is told to look into distance, and the size and position of these images is noted, and then, carefully watching them, he is told to gaze at a near point. No change will be seen in the first image (proving the fallacy of the old theory that the cornea becomes more convex during accommodation), and little change in the third; but the middle image—viz., that from the anterior surface of the lens—becomes distinctly smaller and moves forward, showing that this surface has become more convex.

In accommodation, then, the lens becomes larger in its antero-posterior diameter, and as it does not alter in volume, it becomes narrower in its equatorial dimensions.

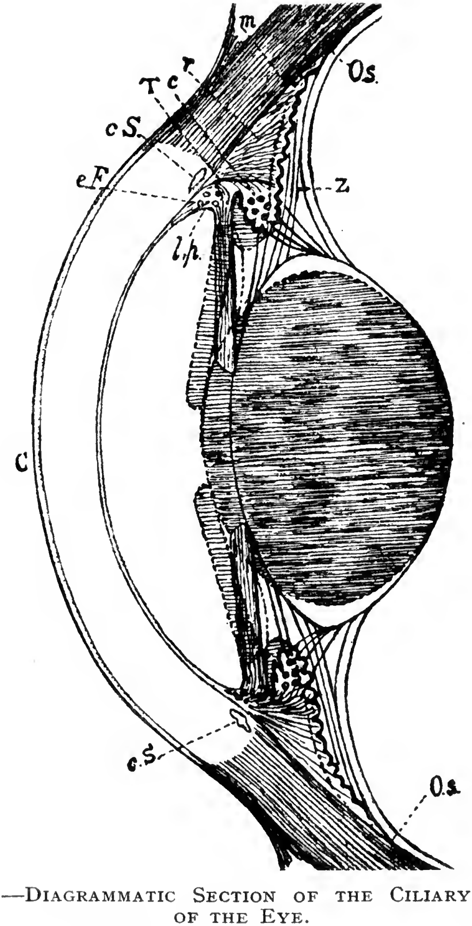


FIG. 26.—DIAGRAMMATIC SECTION OF THE CILIARY REGION OF THE EYE.

C, Cornea; *c S*, Schlemm's canal; *O s*, ora serrata; *l p*, pectinated ligament; *e F*, Fontana's space; *T*, tendinous ring; *m*, meridional fibres; *r*, radiating fibres; *c*, circular fibres of the ciliary muscle; *Z*, zone of Zinn.

The full lines indicate the lens, iris, and ciliary body at rest, and the dotted lines the same in a state of accommodation. (Reduced from Landolt.)

We will now inquire how this change is brought about. According to Iwanoff, the ciliary muscle arises from a tendinous ring (Fig. 26, T) close to the insertion of the iris and Schlemm's canal (*c S*), at the posterior surface of the sclerotic, close to its junction with the cornea. The muscle then passes backwards, and may be divided into three parts: (1) The outermost part or meridional portion, passing into the posterior tendon (*m*), to be inserted into the choroid; (2) the radiating portion (*r*); and (3) the annular portion or circular muscle of Müller (*c*), passing directly backwards and inwards respectively, to be inserted into an agglomeration of fibres called the "zone of Zinn" (*Z*). These fibres arise partly from the ciliary portion of the retina at the ora serrata (*O s*), and partly from the ciliary processes and the intervals between them, and they pass forwards and backwards, to be inserted into the anterior and posterior capsule of the lens.

The annular muscle of Müller is a sphincter, and does the principal work; hence it is always larger in hyperopia, because of the extra accommodation work necessary, and is badly developed in myopia.

There are two theories as to the *modus operandi* of the ciliary muscle when accommodating. The old theory started by Helmholtz, and supported by Hess, is as follows:

When the ciliary muscle contracts, it pulls forwards and inwards the capsule of the lens, the inward pull being specially brought about by the contraction of the circular muscle of Müller. The contraction of the longitudinal fibres pulls forward the choroid and the portion of the ciliary body near it.

By this process, they contend, the tension on the lens capsule is relaxed, and the lens, which has been in a state of compression, is allowed to assume a more convex form.

The new theory advanced by Tscherning maintains

that the action of the ciliary muscle is to *increase* the tension on the fibres of the suspensory ligament, and to alter the lens from a spherical to a hyperboloid form, and this theory is founded on the work of Thomas Young. According to this theory, the lens becomes more conical under accommodation, and the contraction of the pupil, that occurs at the same time, masks the increased aberration which results from the flattening of its periphery.

The posterior surface of the lens does become slightly more convex during accommodation, but it does not change its position, the increase of thickness of the lens being effected by the advance of the anterior surface.

Tscherning's theory of accommodation is entirely supported clinically. Under the Helmholtz theory it is difficult to understand the possibility of meridional asymmetrical accommodation, and as difficult to believe in the possibility of obtaining 20 D of accommodative power which is frequently seen in young subjects. Lastly, the Helmholtz theory is totally against the idea of *rest*.

Amplitude of Accommodation.—At rest, the eye is adapted for the most distant point it can see distinctly—viz., its *punctum remotum* (R); while the greatest possible contraction of the ciliary muscle adapts the eye to the nearest point it can see distinctly—viz., its *punctum proximum* (P), which represents the greatest possible contraction. The force required to change the eye from R to P is called the "amplitude of accommodation," and is represented by the *difference* between the refraction of the eye at rest and the refraction when doing its utmost work.

Donders represented the equation thus:

$$\frac{1}{A} = \frac{1}{P} - \frac{1}{R}$$

or

$$a = p - r.$$

Where "a" equals the numbers of dioptres represented by the accommodation, "p" equals the number of diop-

tres represented by the eye when in a state of maximum refraction—*i.e.*, when adapted for its nearest distinct point—and "r" equals the number of dioptres represented by the eye at rest—*i.e.*, when adopted for its furthest distinct point. In other words, "r" represents the static refraction of the eye.

In *emmetropia*, as R is at "infinity, "r" can be ignored,

$$\therefore a = p.$$

Therefore the amplitude of accommodation is represented by the nearest distinct point; if this is 9 cms. off, "a" = $\frac{100}{9}$ = 11—that is, the power of accommodation is equal to a lens of eleven dioptres.

In *myopia* "r" has a positive value. Take, for example, a person whose furthest distinct point with the eye at rest is 33 cms. (that is, a myope of 3), and suppose that his nearest distinct point is 7 cms.; then

$$\begin{aligned} a &= p - r \\ &= \frac{100}{7} - \frac{100}{33} \\ &= 14 - 3 \\ &= 11. \end{aligned}$$

In other words, 14 would represent his amplitude of accommodation if he were emmetropic; but being myopic to the extent of 3, we must subtract that, which leaves us 11 to represent his amplitude.

In *hyperopia*, as we shall see later, "r" is negative; therefore the equation is—

$$\begin{aligned} a &= p - (-r) \\ &= p + r. \end{aligned}$$

Thus, an eye hyperopic to the extent of 5, having its near point at 25 cms. from the eye, has an amplitude of accommodation equal to a lens of 9. To see 25 cms.

off, the eye requires an accommodation of 4 ($\frac{100}{25}$), but it has already expended 5 for distance, so that

$$\begin{aligned} a &= p - (-r) \\ &= 4 - (-5) \\ &= 4 + 5 = 9. \end{aligned}$$

We thus see that to determine the amplitude or range of accommodation we must find R and P.

R is represented by the refraction of the eye at rest.

P we find as follows:

Take a tape graduated on one side in centimetres, and on the other in corresponding dioptres; the zero-end of the tape is attached to the handle of a frame, into which may be introduced either a perforated diaphragm or a paper with fine print upon it, or threads or hairs; or the ordinary near vision test card and separate measure may be used. The test object is brought towards the eye under examination (the other one being covered) until it begins to appear indistinct; we then read off on the tape the distance of P from the eye, and the corresponding dioptres (p) representing the maximum refractive power of the eye.

If from any cause, such as presbyopia or high hyperopia, the patient's near point is so far that the above tests cannot be employed, we place in front of the eye such a convex glass as will bring the punctum proximum (P) closer, and enable him to read D = ·5 or see the words in the frame, such glass to be, of course, deducted afterwards. Thus, supposing a person with +2 can bring the test object up to 25 cms. and no nearer, we read off on the other side of the tape 4, and we subtract the +2 from this, which gives us p = 2—that is, P is 50 cms. off. If he is an emmetropic presbyope, this represents his amplitude of accommodation. If he is hyperopic to the extent of 6, then

$$\begin{aligned} a &= 2 + 6 \\ &= 8. \end{aligned}$$

Or suppose the patient, being hyperopic and presbyopic, requires $+5$ to read at 33 cms., if his hyperopia $= 6$, then

$$\begin{aligned} a &= p + r \\ &= (3 - 5) + 6 \\ &= 4. \end{aligned}$$

We can also find the amplitude of accommodation by ascertaining the strongest concave glass the patient can "overcome." In emmetropia such glass represents the amplitude of accommodation. In hyperopia the amount of hyperopia must be added, and in myopia the amount of myopia must be deducted.

As an example, we find a patient who is hyperopic to the extent of 2 can still read $\frac{6}{6}$ with -4, but he cannot do so with -5; thus his amplitude of accommodation is $4 + 2 = 6$.

It necessarily follows that to determine the amplitude of accommodation of an eye, its refraction must be accurately ascertained and the patient must wear the full correction of the error when the examination is made.

The **Region of Accommodation** is quite different from the range, and gives very little idea of the work done.

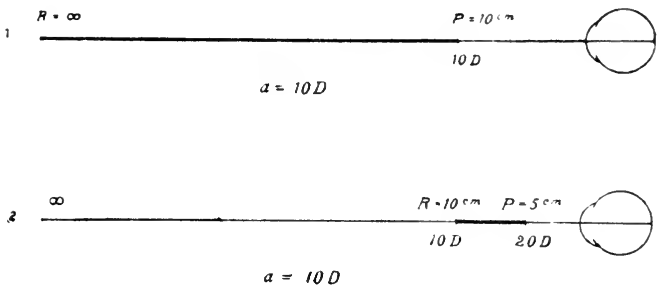


FIG. 27.

Thus, the region of accommodation in an emmetropic eye, as Fig. 27 (1), is from infinity (R) to 10 cms. (P) in

front of the eye, while in Fig. 27 (2), a myopic eye, it is only from 10 cms. (R) to 5 cms. (P) in front of the eye, and yet in each case the same amount of accommodation work is done, which is equal to a lens of 10.

Accommodation is spoken of as absolute, binocular, and relative.

Absolute accommodation is the full amount of accommodation of one eye, the other being excluded.

Binocular accommodation is the full amount of accommodation which both eyes, converging, can exert together.

Relative accommodation is the limit within which accommodation may be increased or decreased, the convergence remaining the same (see Convergence, page 54).

CHAPTER IV

CONVERGENCE

Anatomical and Physiological Considerations.—The orbit contains the eyeball, the optic nerve, muscles, lachrymal gland vessels and nerves, and a quantity of fat. These structures are all firmly connected by a system of fasciæ. Surrounding the eyeball, these fasciæ are condensed in a fibrous capsule—the fascia bulbi or Tenon's capsule. This capsule consists of an external capsule and an internal capsule. It is perforated by the muscles just before their insertion into the globe, and its reflection unites with the cone of fascia surrounding the muscle; prolongations and thickenings of the orbital fasciæ of these muscles are inserted into the margins of the orbit, and constitute the check ligaments.*

The muscles which move the eye are six in number, and, with the exception of the inferior oblique, which arises from the anterior and inner part of the floor of the orbit, they all arise from the apex of the orbit. These muscles may be considered as three pairs, each pair rotating the eye round a particular axis. The four recti—viz., superior, inferior, internal, and external—pass forwards, pierce Tenon's capsule, from which they receive a sheath, become tendinous, and are inserted into the sclerotic not far from the margin of the cornea, the most anterior insertion being that of the internal rectus, which is about 6 mm. from the margin of the cornea. The superior oblique passes forwards to the upper and inner angle of the orbit, where it becomes temporarily tendinous, and passes through a pulley, after which it becomes muscular again, and changes its direction, passing backwards and outwards through Tenon's capsule to be inserted (tendinously) into the sclerotic, at the back and upper part of the eye. The inferior oblique passes outwards and backwards, underneath the inferior rectus, and then between the external rectus and the eye, to be inserted into the outer, posterior, and lower part of the eyeball, not very far from the entrance of the optic nerve.

The axis of rotation of the internal and external recti is vertical, and that of the superior and inferior recti horizontal, with the inner extremity more forward than the outer (Fig. 28). That

* See Maddox, "Ocular Muscles," 1907, page 26.

of the oblique muscles lies also in the horizontal plane, with its anterior extremity tilted outwards.

The movements of the eyeball are produced by the association of various muscles, as shown below:

1. *Elevation.*—The movement of the eye straight up is produced by the superior rectus and inferior oblique, probably

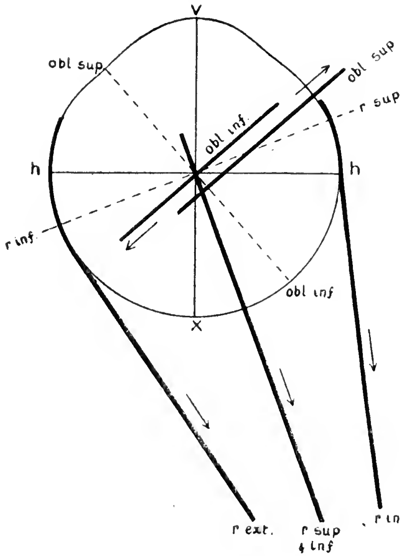


FIG. 28.—DIAGRAM OF THE ATTACHMENTS OF THE MUSCLES OF THE LEFT EYE AND OF THEIR AXES OF ROTATION AS SEEN FROM ABOVE. (MICHAEL FOSTER.)

The attachments of the muscles are shown by the beginning of the thick lines, and the direction of the pull is shown by the arrows. v x represents the visual axis, and h h a line at right angles to it.

The axis of rotation of the internal and external recti, being perpendicular to the plane of the paper, is not represented; that of the other muscles is indicated by the broken lines.

steadied by the internal and external recti, the superior rectus assisting in the elevation of the lid.

2. *Depression.*—Looking straight downwards is produced by the inferior rectus and the superior oblique, steadied by the lateral recti, the inferior rectus assisting in the depression of the lower lid.

3. *Abduction.*—The eye is turned straight out by the external

rectus, assisted at the extremity of its action by the superior and inferior recti.

4. *Adduction.*—The eye is turned straight in by the internal rectus, assisted at the extremity of its action by the superior and inferior recti.

When both eyes look to the right, we have contraction of the

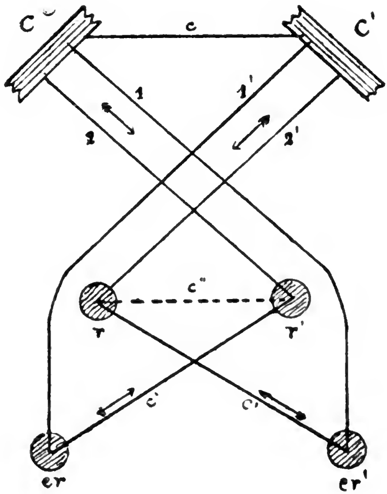


FIG. 29.—DIAGRAM OF THE CONNECTIONS OF THE NUCLEI OF THE LATERAL RECTI MUSCLES. (AFTER ROSS.)

C C′, Cortex of right and left cerebral hemispheres; 1, 2, fibres of the pyramidal tract uniting C, the cortex of the right hemisphere, and r′ and er′, the nuclei of the *left* internal and external rectus; 1′, 2′, fibres of the pyramidal tract connecting the cortex of the left hemisphere with r and er, the nuclei of the *right* internal and external rectus muscles; c, fibres of the corpus callosum uniting identical regions of the two hemispheres; c′, commissural fibres connecting the spinal nucleus of the internal rectus of one eye with that of the external rectus of the opposite eye; c″, suggested commissural fibres connecting the nuclei of the two internal recti.

right external and left internal recti, and when they look to the left, contraction of the left external and right internal recti.

Movement of the eyes up and in is produced by 1 and 4—viz., superior rectus, inferior oblique, and internal rectus, movement down and out by 2 and 3, and so on.

The external rectus is supplied by the sixth nerve, the superior oblique by the fourth, and the others by the third.

Convergence of the eyes is produced by the associated movements of both the internal recti. The nuclei (*r r'*, Fig. 29) of that part of the third nerve which supplies these muscles may be connected by fibres (*c"*), illustrating the principle that there is bilateral association of the nerve nuclei of muscles bilaterally associated in their action (Broadbent). This explains the convergence of a covered eye. A. Graefe says that one of the factors causing the covered eye to converge is a " Convergenzgefühl," or, as Hansen Grut expresses it, a " Nahebewusstsein "—a consciousness of nearness. Landolt denies this, and asserts that the excluded eye fixes correctly through the connection between accommodation and convergence alone.

It is important to remember that when a stimulus passes primarily to the nucleus of the internal rectus, it is associated with the same muscle of the opposite side, and convergence takes place; whereas the conjugate movements of the eyes to the right or left are produced by stimuli passing *primarily* to the nucleus of the *external* rectus, which nucleus is connected with the nucleus of the internal rectus of the opposite side (Fig. 29). We may have both these stimuli occurring at the same time—viz., primary stimulus to the internal recti to converge, and to the external rectus of one side associated with the internal rectus of the other side—to produce lateral movements of the eyes.

The oculo-motor centre (Fig. 30, O.M.C.) is situated beneath the floor of the aqueduct of Sylvius. It includes (1) the accommodation centre (A), lying most anteriorly near the middle line, and (2) the pupil constrictor centre (P). The nucleus of the internal rectus (I.R.) lies further back. Filaments pass along the third or oculo-motor nerve from these centres to the ciliary muscle, the sphincter of the iris and the internal rectus, and are so associated that contraction of the ciliary muscles for accommodation, of the pupils, and of the internal recti for convergence, are all three associated in their actions. One impulse—viz., a psychical impression, a wish to look at a near object—passes from the motor centre in the cortex of the brain to these nuclei, and the result of this one impulse is the united action of these different muscles; the action is not always simultaneous, for convergence often lags behind accommodation (see page 56).

Many people can voluntarily squint inwards, but they will be found to accommodate for a near point at the same time; some few can, however, do so without accommodating, and in such cases the psychical impression probably passes straight to the nucleus of the rectus internus by PS' (Fig. 30).

Binocular Vision.—Man has binocular vision—that is, the image from an object falls upon the retina of each eye simultaneously, and in normal binocular vision on exactly the same region of the retina; for if the images

did not overlap, two images would be seen, and so-called "double vision" would be the result. The absence of double vision does not necessarily imply the presence of normal binocular vision with fusion of the two images, for one eye may be blind or its image suppressed by the brain (monocular vision). Many people use one eye only, for years, without discovering the fault. The best and quickest test for determining whether binocular

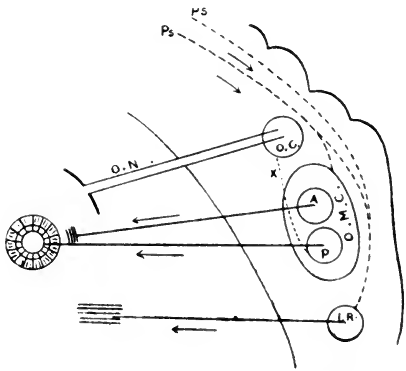


FIG. 30.—SCHEME SHOWING THE OCULO-MOTOR CENTRE AND SOME OF ITS CONNECTIONS. (ADAPTED FROM ERB.)

PS, Psychical impression (the wish to accommodate being the stimulus); PS′, psychical impression for voluntary converging strabismus; A, accommodation centre with motor nerve to ciliary muscle, and P, centre for the sphincter of the iris with motor nerve, the two forming the oculo-motor centre, O.M.C.; I.R., internal rectus centre, with motor nerve to internal rectus muscle; O.N., optic nerve from retina to O.C., optic centre, and connected with P, the pupillary centre; X is the seat of the lesion causing reflex pupillary immobility.

vision is present or not, is Snellen's apparatus, described on page 153.*

Whereas, then, in discussing accommodation we considered the eye simply as an optical apparatus, now we

* Any of the tests for latent deviation, mentioned later, may also be employed.

must consider the two eyes together as forming *one whole*, and on their proper associated movements must depend perfect binocular vision.

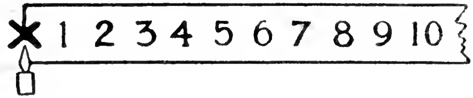
If binocular vision be impossible, through some great defect of the optical apparatus or the muscles, no attempt will be made to produce it, and no strain will follow. On the other hand, apparently normal binocular vision may exist; but to produce this, a demand in excess of the power is put upon a muscle or a set of muscles, and the result is strain, either producing or tending to produce the symptoms of muscle strain.

The Relation of the Two Eyes to Each Other in Normal Distant Vision.—Michael Foster says that the *primary position* of the eyes is "that which is assumed when, with the head erect and vertical, we look straight forwards to the distant horizon; the visual axes of the two eyes are then parallel to each other and to the median plane"—that is, in ideal binocular *distant* vision, the eyes being at rest and all the muscles in equilibrium with respect to each other, *the visual axes are parallel.*

Test for Latent Deviation of the Eyes for Distance.—If a person with normal vision be directed to look at an object in the distance, and one eye be covered for twenty or thirty seconds, if there be any latent deviation it becomes as a rule manifest, and on uncovering the eye there will be diplopia for a brief space of time, the covered eye moving (in order to fuse the two images)—in, if there be latent divergence, and out, if convergence. A more accurate method of conducting this test is to destroy the possibility of binocular vision—*i.e.*, fusion—by means of a prism, with its base up, placed before one eye, or, better still, by the apparatus suggested by Maddox, called the "glass rod test"; by which means we can not only at once detect concealed deviation, but can also measure the amount.

The Maddox Test.—A glass rod (Fig. 31, a) is arranged

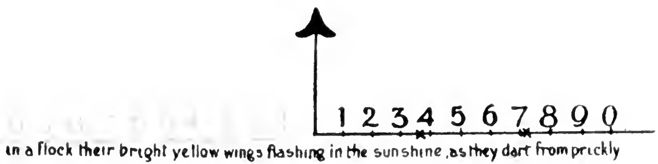
Maddox Distance Scale



Horizontal latent deviations Vertical latent deviations

Orthophoria Exophoria Esophoria Orthophoria Left Hyperphoria Right Hyperphoria

(In the above illustrations the glass rod is before the Right Eye)



Maddox Scale for ¼ Metre

in a metal disc, which fits into the trial frame.* If this rod be placed before one eye, the other eye remaining uncovered, and a small flame be looked at from a distance of more than 4 metres, the eye in front of which the rod is placed sees the flame merely as a streak of light, and, the images of the two eyes being so dissimilar, there is no desire on the part of the brain to fuse them; consequently the two eyes assume their position of rest. If the rod be placed horizontally in front of the right eye, there is a vertical streak of light, and if this streak coincide with the image of the candle seen by the left eye, the visual axes are parallel (orthophoria); but if it

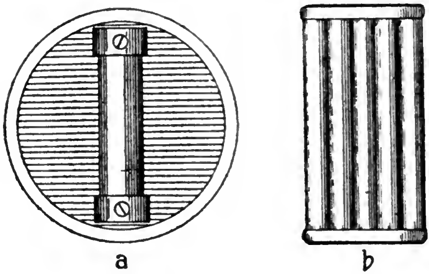


FIG. 31.

do not, then when the streak is on the same side as the rod (in this case the right side) there is latent convergence (homonymous diplopia), when on the other side there is latent divergence (crossed diplopia). If a scale be used as suggested by Maddox (see plate), the number on the scale through which the streak of light passes records the amount of diplopia; or prisms may be put up in front of the other eye, or the rotary prism used (see page 7). The weakest prism that causes the two images to coincide records the amount of diplopia. The Maddox

* Fig. 31, b, represents a simple form of this apparatus which can be made by uniting four or five glass rods with sealing-wax. This must be held before the eye, as it does not fit into a trial frame.

distance scale is marked for 5 metres, and roughly every $3\frac{1}{2}°$ represents a metre angle. To be quite exact, every $3° 40'$ or 32 cms. is a metre angle. If the scale be used at 4 metres, then every 25·5 cms. represents a metre angle.

If we wish to measure vertical deviations, we turn the rod vertically, and thus obtain a horizontal streak of light. If this streak pass through the middle of the flame there is no vertical deviation, but if it be above or below there is hyperphoria of that eye which sees the lower image—*i.e.*, if the streak of light be lower there is a tendency to upward deviation (latent hyperphoria) of the eye in front of which the rod is placed. To measure the vertical deviation we must use a scale, similar to that in the Plate, placed vertically.

Before this test is applied any refractive defect must be corrected. By making a large number of examinations by this method, we can easily prove the correctness of the statement, that, *for all practical purposes, the visual axes of the two eyes in normal binocular vision are parallel.* So much for what is called the "static equilibrium" of the ocular muscles. Now we proceed to examine the dynamic condition—that is, the relation of the muscles in binocular near vision; in other words, during *convergence.*

Convergence "is the direction that the eyes must give to their lines of fixation in order that they may be simultaneously directed toward the point of fixation." When both eyes are fixing an object 6 metres (or more) distant, they are parallel, and C (which represents convergence) = 0; when the eyes simultaneously fix an object 1 metre off in the median line, both internal recti contract and the eyes converge; convergence is then said to be 1 metre angle, C = 1 m.a. This metre angle is the unit of convergence. If the eyes converge to a point 50 cms. off, then $C = \frac{100}{50} = 2$ m.a.; if 20 cms. off, $C = \frac{100}{20} = 5$ m.a.; and if the object be 3 metres off,

$C = \frac{1}{3} = \cdot 33$ m.a. In Fig. 32, E E is the base line connecting the two eyes, and E R′ and E R′ are two lines at right angles to this base, and therefore parallel. If the two eyes look at a point R, the angle R′ E R is the "metre

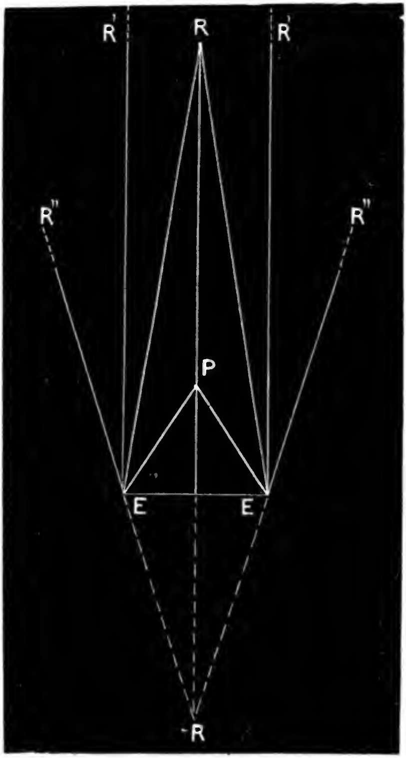


FIG. 32. (AFTER NAGEL AND LANDOLT.)

angle," or, better still, as R′ E R is equal to E R P, the latter may be called the "metre angle." To Nagel belongs the credit of devising this method of measuring the amount of convergence. The metre angle (or "Meter-

winkel," as he calls it) of convergence corresponds to the dioptre of accommodation. Thus, an emmetrope who is fixing binocularly a point 1 metre off is using 1 dioptre of accommodation, and convergence is 1 m.a.; and if the point be 25 cms. off, he is using 4 dioptres of accommodation, and his amount of convergence is $\frac{100}{25} = 4$ metre angles, and so on.

Amplitude of Convergence.—We again use Donders' formula, and, expressing the equation in metre angles,

$$c\,a = c\,p - c\,r,$$

where "c a" represents the amplitude, "c p" the maximum, and "c r" the minimum, of convergence.

When R is at finite distance (Fig. 32), we have $c\,a = c\,p - c\,r$; that is, the amplitude of convergence is the amount of convergence required to direct the visual axes of the two eyes simultaneously to the point P, starting from the binocular distant point R. When the visual axes are parallel, "r" can be ignored, and the equation stands—

$$c\,a = c\,p.$$

When the visual axes diverge, E R″, E R″, the axes will, if prolonged backwards, meet at a point − R, which is negative; the equation will then be—

$$c\,a = c\,p - (-\,c\,r) = c\,p + c\,r.$$

We distinguish the equation from that used in accommodation by prefixing or affixing a "c," thus:

$$c\,a = c\,p - c\,r,$$

or

$$a^c = p^c - r^c.$$

The Punctum Remotum of Convergence.—*Just as the punctum remotum of accommodation is the expression of the* refraction *of the eye when completely at rest, so the punctum remotum of convergence is the expression of the*

position *of the eyes when at rest—that is, when the impulse to fusion brought about by binocular vision is removed*—so that to find R we must find the *latent position* of the eyes for distance. This we do by the Maddox test, and the number of metre angles read off on the scale gives us "c r." When there is no latent deviation "c r" = 0, when there is latent divergence "c r" is negative, and when latent convergence it is positive.

To find "c p," the maximum of convergence, we direct the person to fix binocularly a small test object held, say, $\frac{1}{3}$ metre from the eyes, equidistant between them and on the horizontal plane of the eyes. This may be a fine hair or wire stretched vertically in a frame, or it may be a luminous slit, as in Landolt's ophthalmodynamometer (Fig. 33); when the object is approached to such a distance that the test line appears double, we measure off the distance in centimetres, and divide this into 100, which gives us the number of metre angles that "p" is equal to. Suppose "c P" to be 10 cms., "c p" = $\frac{100}{10}$ = 10 m.a., and if c R be at "infinity,"

$$a = 10;$$

but if there be latent divergence, say of 1 m.a., r = − 1 m.a., and

$$a = 10 - (-1) = 10 + 1 = 11 \text{ m.a.}$$

In this test we must be careful to distinguish between mere haziness of the test object, which is the result of its being within the patient's accommodation near point, and doubling of it, because the near point of convergence is often nearer than that of accommodation. We should, therefore, always first ascertain the accommodation near point in each eye.

It is generally considered that the normal amplitude of convergence is 10·5 m.a., although it may be 15 or even 17 m.a.

The Relative Range of Accommodation and Convergence.—If the *latent* position of the eyes be tested, not only during the fixation of distant objects and of objects at a reading distance, but also for intermediate distances of fixation, it will be found that, as a rule, there is quite a gradual lagging of the non-fixing

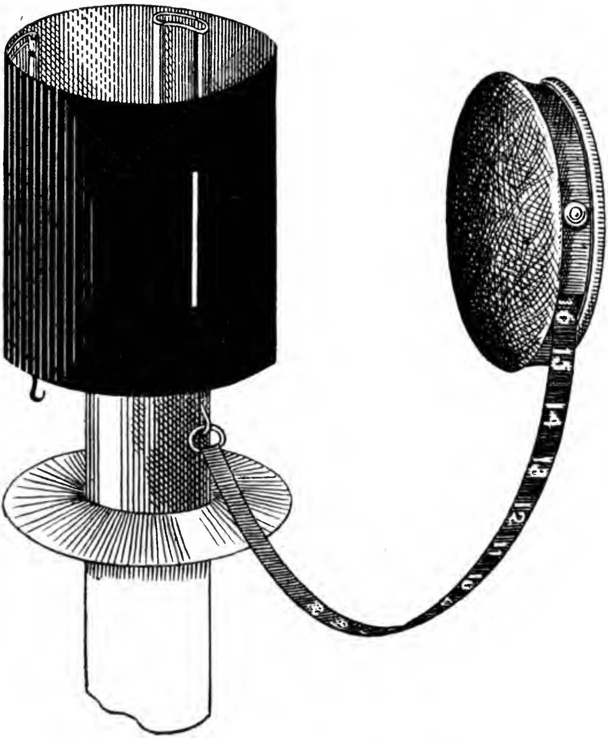


FIG. 33.—LANDOLT'S OPHTHALMO-DYNAMOMETER.

This apparatus rests on a candle, which, when lighted, causes the slit in the cylinder to appear as a luminous line.

eye behind the fixing one: a *gradual* increase of latent divergence. This divergence is greater in myopia and less in hyperopia than in emmetropia. Fig. 34 represents the average curve of relative latent deviation in emmetropia. According to this figure, we see that with parallelism, or a condition almost approaching to

parallelism for distance, there is $\frac{1}{2}$ metre angle of divergence on accommodating for $\frac{1}{2}$ metre, and a whole metre angle for $\frac{1}{4}$ metre accommodation—that is, that whereas, with both eyes fixing, on accommodating for $\frac{1}{4}$ metre, 4 D of accommodation is used, and both eyes converge to a point using 4 m.a. of convergence, when the possibility of fusion is removed both eyes only converge to a point $\frac{1}{3}$ metre off, using 3 m.a. of convergence.

This is no proof of the existence of "insufficiency" of convergence; all it shows is that the intimate relation between accommodation and convergence is not absolute.

All the more, then, should we expect to get latent divergence for near points when there is initial latent divergence for distance. When there is initial latent divergence for distance, the "lagging" of the convergence behind the accommodation for near points is

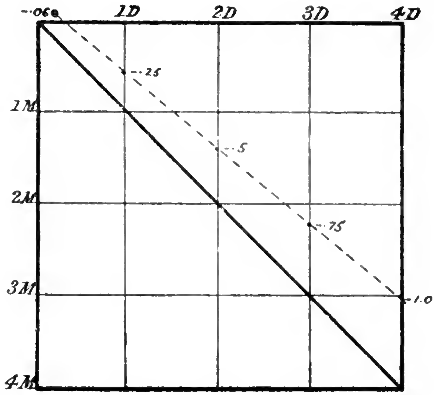


FIG. 34. (AFTER BERRY.)

more marked than when the position of the eyes is parallelism, and this produces a "convergence insufficiency." We can ascertain the presence of latent deviation in near vision by the Maddox test. A scale (see plate, page 45) is held $\frac{1}{4}$ metre from the eyes, and a prism of 12°, base up, is held before the right eye. The scale consists of a horizontal line with fine print below it, in the centre of which is an arrow pointing upwards. The line is divided in degrees which are marked by figures, black on the right of the arrow, red on the left. Every $3\frac{1}{2}$° from the arrow is marked by a small cross representing 1 m.a. The prism causes two lines and two arrows to be seen, and the patient is instructed to fix the upper arrow, or, better, the fine print just below it. When there is no latent deviation the two arrows are in a vertical line. When the lower arrow points to the left (red side) of the upper arrow there is latent divergence, and when it

points to the right (black side) there is latent convergence for ¼ metre, the amount of deviation being read off on the scale. Graefe's "dot and line" test is inferior to the foregoing, as it does not record the amount of the defect.

Maddox maintains as a result of his experiments that in near binocular vision there is always relative divergence—that is, convergence always lags behind accommodation. This convergence is composed of three factors: (1) "initial convergence" (this, of course, exists only when there is latent convergence) due to the relaxation of the external recti which are maintaining parallelism (*p p*, Fig. 35), and the eyes assuming their position of rest *i i*; (2) accommodative convergence—*i.e.*, the amount of convergence which is called forth by the accommodative effort which brings the axes to *a a*; and, lastly, (3) the "fusion supplement," which is the result of the desire for single vision, and brings the axes to *o*. This "fusion supplement" is demon-

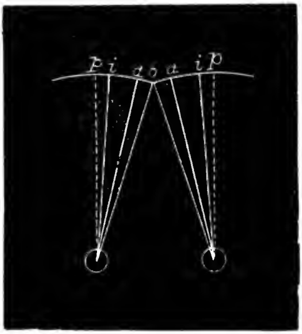


FIG. 35. (MADDOX.)

strated by holding a pen midway before the eyes of a patient at the distance of the convergence near point, and telling him to fix the tip of the pen; if now one eye is covered, this covered eye will markedly turn out, and, on uncovering, the patient will for a moment have diplopia, the eye making an incursion to recover binocular vision. The amount of the excursion on covering, or incursion on uncovering, represents the fusion supplement which the demand for binocular vision calls forth. This experiment can be made on most people, and is no proof of "insufficiency" of convergence.

Although accommodation and convergence are intimately connected, this connection is not absolute. We can prove this experimentally by altering our accommodation without changing our convergence, as in looking at an object with both eyes before which we place weak convex and concave glasses, and also by altering our convergence without changing our accommodation

by placing before the eyes weak prisms, base in or out. The amount of dissociation between the accommodative and convergence efforts is limited, and varies *with* and *in* the individual; it can be increased by practice, and it differs for varying degrees of accommodation and convergence. Fig. 36 shows the relative amount of accommodation that can be used with different degrees of convergence in an emmetrope aged 15.

The horizontal figures record the degrees of convergence in metre angles, and the vertical figures record the degrees of accommodation in dioptres. The diagonal D D represents the

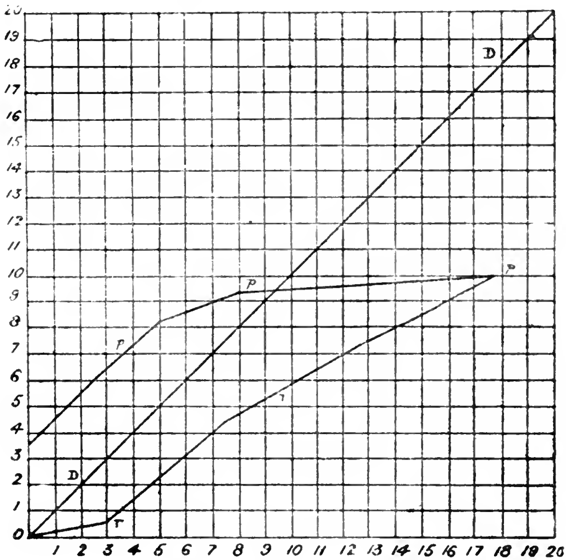


FIG. 36.

convergence, starting from zero—*i.e.*, "infinity"—and stopping at 5 cms. (20 metre angles). The vertical divisions between the upper curved line *p p* and the diagonal, represent the amount of maximum or positive part of accommodation, ascertained by the strongest concave glass that can be borne without prejudice to binocular and distinct vision, for any given point of convergence, and those between the diagonal and the lower curved line *r r* represent the amount of minimum or negative part of accommodation, ascertained by the strongest convex glass. Thus, take convergence for 6 m.a.: above we have 2·5 dioptres of positive accommodation, and below 3 of negative accommodation—that

is, the relative amplitude of accommodation for 6 m.a. of convergence is 5·5 in this individual. It will be seen that when the convergence has reached 10 m.a. the whole of the range of accommodation is negative.

Accommodation remaining fixed, we can estimate the amount of relative convergence by means of prisms; the strongest prism, base out, that can be borne with fusion represents the positive, and base in, the negative part, of the amplitude of convergence, and, as Landolt has pointed out, we find that Fig. 36 can be made use of to represent this. The diagonal D D represents the accommodation starting with eyes adapted for infinite distance; the positive portion of the relative range of convergence is on the right of the diagonal, and is represented by the horizontal divisions between D D and *r r*, and the negative portion is on the left. Thus for accommodation at 25 cms.—*i.e.*, 4 dioptres—we see that we have 3 m.a. on the right and 3·5 m.a. on the left—that is, while maintaining the same amount of accommodation, an adducting prism producing a deviation of 3 m.a., and an abducting prism requiring a diminution of 3·5 m.a., can be overcome by the eyes. Thus for 4 dioptres of accommodative power in this individual, an amplitude of convergence of 6·5 m.a. exists.

It is fortunate for the ametrope that this dissociation between accommodation and convergence is possible. A hyperope of 3 D who fixes an object binocularly 33 cms. off must use an additional 3 of accommodation—that is, he must use 6 altogether—but he will only require to converge to 3 m.a. If the association between accommodation and convergence were absolute, he would either have to converge to 6 m.a., and consequently squint, and thus lose binocular vision, or he could keep binocular vision on the condition that he did not accommodate for this near point; in other words, he has the choice between distinct vision and binocular vision—he cannot have both. Many hyperopes dissociate these two efforts, and can by practice and "nerve education" accommodate in excess of their convergence (see page 90). The difference in the power to dissociate these two efforts is one of the explanations of the well-known fact, that of two individuals having the same refractive defect, one will squint and the other not.

The same necessity for dissociation between convergence and accommodation occurs in myopia. A myope of 3 D can see an object 33 cms. off without any accommodation, but must converge to the extent of 3 m.a. Thus he uses his *convergence* in excess of his accommodation.

Donders stated that accommodation can only be maintained for a distance when, in reference to the negative, the positive part of the relative range of accommodation is tolerably great, and that the relative range of accommodation in ametropic eyes is quite different from that of emmetropic eyes, but that it tends to approach the latter when the correction of the error has been worn for some time.

CHAPTER V

THE OPHTHALMOSCOPE

To understand the action of the ophthalmoscope, the following facts connected with the **Optics of Reflection** should be remembered:

1. When light falls on a plane mirror (Fig. 37, A B), the angle of incidence is equal to the angle of reflection. The incident ray F D makes with the perpendicular P D an angle F D P, and the reflected ray D E also makes

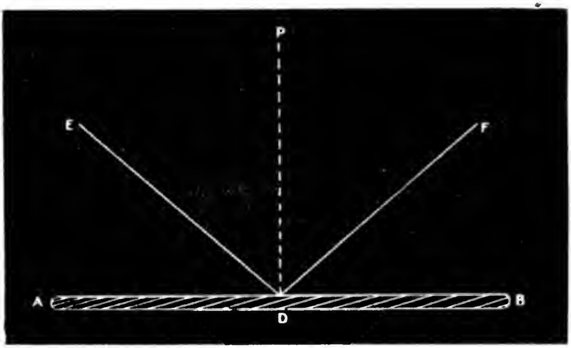


FIG. 37.

an angle E D P, and these two angles are equal to one another. Both incident and reflected rays are in the same plane, which is perpendicular to the mirror.

2. When parallel rays of light (Fig. 38, A B and C D) fall on a concave mirror, they are reflected to a focus (F) in front of the mirror, and this principal focus is midway

between the mirror and the centre of curvature of the mirror (O) and on the principal axis.

3. Rays of light coming from a point near the mirror, but beyond its centre, as at L (Fig. 38), come to a focus (l) between the centre and the principal focus, and the two points are conjugate foci.

The Ophthalmoscope.

If by some contrivance we can manage to send rays of light from a spot in front of our eye into another eye, we shall get some of those rays returning to our eye after

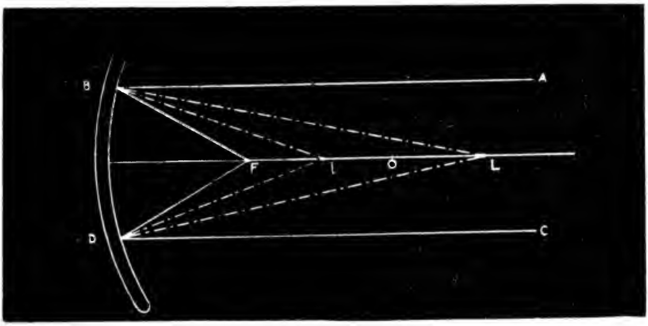


FIG. 38.

being reflected from the retina of the observed eye, if the media be clear, and the pupil of the observed eye, instead of appearing black, will appear red.

This can be done in the simplest manner by a piece of glass plate. If *Obd* is the observed eye, and *Obr* the observer's eye (Fig. 39), in front of which is inclined a glass plate G L, the rays of light passing from L are reflected partly at G L into *Obd*, return along the same path, passing through the plate, and enter the observer's eye. As only a few rays find their way to the observer's eye, the light is very feeble. This was the principle of Helmholtz's first ophthalmoscope, and he improved

it by placing together several glass plates, and thus increasing the luminosity. If for these glass plates a mirror with a central hole is substituted, more rays still will pass into the eye; and these rays returning, more will pass through the hole in the mirror into the observer's eye, and a brighter image of the fundus will be seen. A still greater improvement results if we use a *concave* mirror, as the light is more concentrated.

Such is the simple ophthalmoscope—viz., a mirror with a central sight-hole supported on a handle.

The ophthalmoscope has been further improved by adding an arrangement of lenses of different strength,

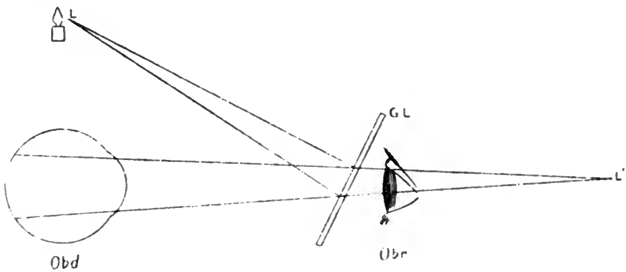


FIG. 39.

which can be turned into position in front of the sight-hole, so that if the eyes of the observer or observed are ametropic, a clear image of the fundus can be obtained by the correcting lens.

The Qualities of a Good Refraction Ophthalmcscope.—The mirror should be concave, with a focus of from 14 to 17 cms. It should be oblique, and capable of being turned round so that it can be used for either eye. This obliquity of the mirror enables the observer to approach very near the observed eye without cutting off any of the light, and also permits the correcting glass, when used, to be in a position parallel to the vertical plane of the eye. When the oblique mirror is not required, as in the "indirect" method and in the "shadow test," a "straight"

mirror should be substituted for it. This can be done by changing the mirrors, or, better still, by an arrangement like the nosepiece of a microscope, to which both mirrors are attached, either of them being turned into position as required. A further improvement can be made by the "straight" mirror being plane on one side and concave on the other, and fixed with a spring hinge, so that either side of the mirror can be used as desired. The mirror should be perforated; imperforate mirrors (with a central hole in the silvering) are not so good, as the glass reflects some of the light that should enter the observer's

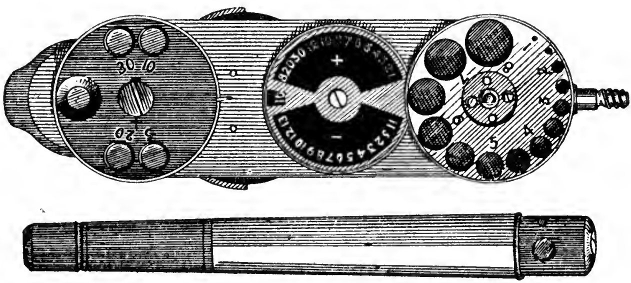


FIG. 40.—MORTON'S OPHTHALMOSCOPE.

The rotating wheel is made to serve as a pupillometer, the discs being numbered from 1 to 8 mm.

eye. The aperture in the mirror should not be too small, otherwise too little light will reach the eye of the observer; its diameter should be about 3 mm. anteriorly (the glass side), and somewhat wider behind, and the sides of the tube should be well blackened. The correcting lenses of the ophthalmoscope should not be too small; they should have a diameter of not less than 5 mm. There should not be too many of them, and never more than two superimposed. The best plan is to have the glasses ordinarily used arranged round the rim of one disc, and those less used arranged, either on another disc, or on a movable quadrant. The number

of ophthalmoscopes on the market is large, but the best, and certainly the most popular, is Morton's (Fig. 40).

FIG. 41.—ELECTRIC OPHTHALMOSCOPE.

The Electric Ophthalmoscope (Fig. 41).—This instrument has completely revolutionized direct ophthalmo-

scopy. The management of the light, when using the old-fashioned instrument, has always been a trouble to the beginner or the practitioner who only occasionally uses the instrument; this trouble is removed in the electric ophthalmoscope because the light is concealed in a tube near the mirror and is fed by a battery in the handle. But even for the oculist who is an adept at using the old instrument the advantages of the electric ophthalmoscope are very marked. As the light has not to be considered, the instrument can be brought so near the eye that it can almost touch the cornea, and consequently a dark room is not necessary, as, by turning the patient with his back to the window, we can easily examine the whole of the fundus, and, moreover, the patient can be examined in any position.

A further improvement is obtained by using a **Marple Mirror.** This mirror, instead of having a central

FIG. 42.—THE MARPLE MIRROR.

opening, has a U-shaped one (see Fig. 42), with the result that there is little or no reflex from the centre of the cornea, and it is often quite possible to examine the macula through a pin-point pupil.

With this instrument and a combined concave and plane mirror (Fig. 50, page 83), and a focusing lens, no further apparatus is required, and the old-fashioned refraction ophthalmoscope can be dispensed with.

The convex lens or focus glass used in the "indirect" method should have a focus of about 8 cms.—*i.e.*, be about 13 D—and should have a diameter of about 6 cms. The lens usually supplied with ophthalmoscopes is much too small. The glass should be kept clean and free from scratches.

The Different Methods of Examining the Eye with the Ophthalmoscope.

1. The indirect method.
2. The direct method.
3. The "shadow test," or retinoscopy.

The patient should be in a darkened room.

The light used should be on an adjustable bracket if possible; any kind of light will do if it has a broad, steady, white flame, but the electric light in a ground-glass globe is the best, as it gives off less heat.

Before commencing the ophthalmoscopic examination, the eye should be thoroughly examined by the oblique or focal illumination. For this purpose put the light on a level with the patient's eye, on the same side as the eye to be examined, and about 12-15 inches from it, and with the focus-glass throw a luminous spot on the cornea. By moving the lens about, the whole surface of the cornea, the anterior chamber, iris, and anterior surface of the crystalline lens, can be examined. This examination is further aided by viewing the illuminated spot through a strong magnifying-glass, and one of the best is Voigtlaender's. This preliminary examination gives valuable information as to the translucency of the media, etc.

1. **The Indirect Method.**—Place the light close to the patient's head and a little behind, so that no light can reach the eye to be examined directly.

Use the " straight " concave mirror, holding it about 15 inches from the eye, thus lighting up the fundus, and making the pupil appear red (if the media are transparent), and detecting opacities of the cornea, lens, and vitreous (the latter are best seen with a plane mirror and faint light).

Still using the same mirror, put up the focus-glass, holding it by the left index-finger and thumb, and

steadying it by resting the remaining fingers of the left hand on the patient's brow. By this means an inverted image of the fundus is seen. This is called the "indirect method."

The observer recognizes that the picture is inverted by slightly moving his head or the focus-glass, and finding that the image moves in the opposite direction.

The manner in which this inverted image is formed is shown by the following figures.

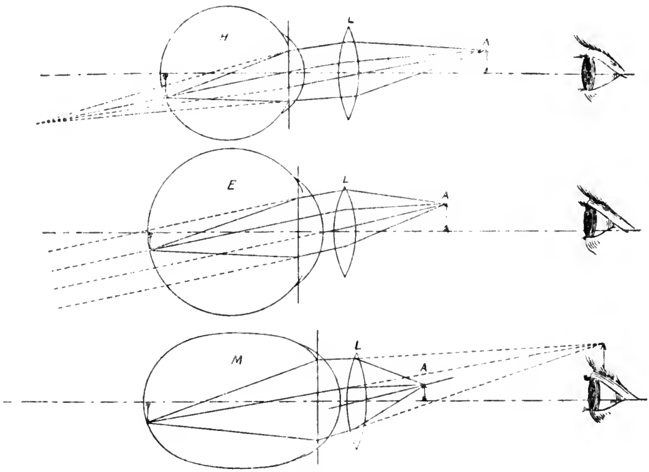


FIG. 43. (AFTER FICK.)

The focus-glass held in front of the eye makes the eye myopic, and, according to the refraction of the eye, this inverted image will be nearer or further from the lens.

When the observed eye is emmetropic, the rays coming from the eye (Fig. 43, E) are parallel, and focus at the principal focus of the focus-glass; and, moreover, as the rays emerging from the eye are parallel, it does not matter where the focus-glass is placed; nearer

or further from the eye, the image must necessarily always be the same size.

In hyperopia (Fig. 43, H) the rays emerging from the eye are divergent, and, passing through the focus-glass, they form a larger image than in emmetropia, and this image is further from the lens *in front* of its principal focus; on withdrawing the lens from the eye, the image is formed on the other side of the lens, nearer and smaller.

In high hyperopia the image is so far in front of the focus-glass that the observer will have either to move back, or to accommodate, in order to get a distinct view of the inverted image.

If with the mirror alone, still held at some distance from the eye, we can recognize fundus details *not inverted*—that is, in their true position—we are dealing with *high hyperopia.*

In myopia (Fig. 43, M) the rays emerging from the eye are convergent, and form an inverted aerial image in front of the eye, and the focus-glass shows this image smaller than in emmetropia, and nearer to the lens—in fact, within its principal focus; on withdrawing the lens the inverted image becomes larger.

In high myopia no focus-glass is required to see the fundus, as the rays proceeding from the eye are so convergent that they come to a focus at the punctum remotum and form an *inverted* image.

In astigmatism the disc may appear oval, and the shape will alter as the focus-glass is withdrawn, according to the refraction of the different meridians.

The advantages of the indirect method are—

1. The examiner is further from the patient than in the direct method (a distinct advantage in dealing with certain patients).

2. A general "bird's-eye" view of the fundus is obtained.

3. No correcting glasses are needed in the ophthal-

moscope; thus, a simple concave mirror with a central hole is sufficient.

4. It is sometimes easier to see the fundus when the pupil is small.

In looking at the right disc, the patient should be directed to look past the observer's right ear, for the disc is on the nasal side of the posterior pole of the eye, and on looking at the left disc he should look past the left ear. It is important to remember that the patient must look with the eye *not* being examined; therefore, in examining the left eye by this method, take care not to obscure the right eye with the hand that is holding the focus-glass.

2. **The Direct Method.**—As already stated above, this method is much simplified by the use of the electric ophthalmoscope. If the old-fashioned instrument is used the light must be brought quite close to the patient's head and slightly behind, and on the same side as the eye to be examined. The observer sits (or stands in a stooping position) close to the patient, and on the same side as the eye to be examined, using his right eye for the patient's right eye, and his left for the patient's left.

Use the refraction ophthalmoscope (without the focus-glass) and the oblique concave mirror. Holding the ophthalmoscope a few inches from the eye, reflect the light on to the eye and observe the red pupillary reflex through the central hole of the mirror, and then, without allowing the light to leave the eye, approach the eye as near as possible; in fact, the observer's forehead ought to touch the patient's forehead. The fault that most beginners make is not getting near enough to the eye. The observer must not accommodate, but look, as if trying to see through the patient's head, into distance. If the observer or patient have an error of refraction, the wheel of the ophthalmoscope must be turned until the suitable glass is found. To see the macula, the patient should

be told to look horizontally, in front; if the disc is to be examined, he should look slightly to the nasal side.

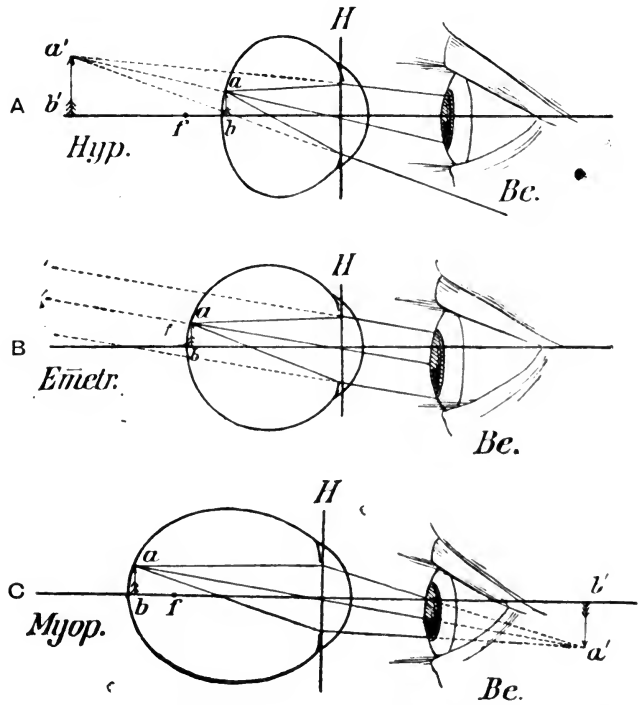


FIG. 44.—EXAMINATION OF THE ERECT IMAGE WHEN THE EYE EXAMINED IS HYPEROPIC, EMMETROPIC, OR MYOPIC. (HAAB, AFTER FICK.)

In each figure three rays are shown emanating from a luminous point on the eye-ground. In hyperopia they diverge after leaving the eye, in emmetropia they are parallel, in myopia they converge: *f*, the posterior focus; *H*, principal plane of the dioptric system of the examined eye; *Be.*, observer. The ophthalmoscope is not shown.

Only a small portion of the fundus can be seen at one time, but this portion is considerably magnified

(about 15 diameters), and consequently the minutest details are visible.

By this method the refraction of an eye can be estimated, which as an objective method has, of course, a distinct advantage.

The first duty of the observer—and most beginners find this very difficult—is to relax his accommodation. The person whose eye is being examined must also relax his accommodation, which can be done by directing him to look at some object 5 or 6 metres off with the other eye, or, better, by paralyzing the ciliary muscle with a cycloplegic. If both the observer's and

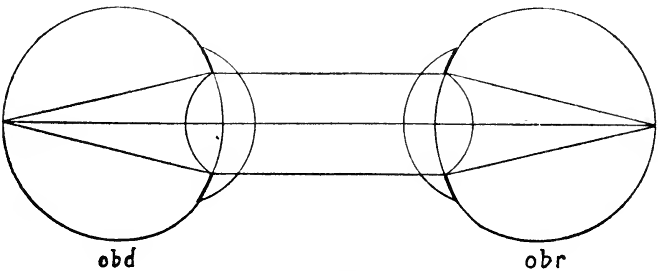


FIG. 45.

the observed eye are emmetropic, all the details of the fundus will be clearly seen (Fig. 44, B). We can easily understand this, when we remember that rays passing from the mirror to the back of the eye that is being examined, are reflected as parallel rays if the eye be not accommodating and be emmetropic, and that parallel rays must be focused on the fundus of the observing eye if it also be emmetropic, and its accommodation be relaxed (Fig. 45). If, on the other hand, the observer's eye under these circumstances accommodate, the image, instead of being sharp, is blurred. It is not only necessary to observe these rules in order to get a clear picture of the fundus, but it is of para-

mount importance if we wish to estimate correctly the refraction of the eye we are examining. For this reason it is important that the observer should estimate his own refraction, and, if there be any error, correct it.

If the observer be myopic, the fundus will be indistinct, just as is the case with all distant objects, for the rays coming from the observed eye are parallel—that is, as if coming from a distant object. In order, therefore, to obtain a clear view of the fundus, the myope must use a concave glass, and the weakest concave glass he can see distinctly with will be the measure of his myopia, if his accommodation be relaxed.

A hyperopic observer is in a somewhat better position, because he can see the fundus if he accommodates; but as he must relax his accommodation in order to estimate the refraction of the eye he is examining, he must first find his own refractive defect and correct it. Unless he had his defect properly corrected in early youth, he has become so accustomed to use his accommodation that it will be most difficult—almost impossible—for him to relax it, and the probability is that, although the convex glass he uses corrects his defect, he nevertheless cannot help using some accommodation, and will thus overcorrect himself, rendering himself myopic. It necessarily follows, therefore, that it is most difficult for a hyperope to estimate the refraction of an eye correctly by this method. He should use some other method, such as the "shadow test," which will be explained later.

We have supposed up to now that the observed eye was emmetropic. We will proceed to examine the conditions that exist when the observed eye is myopic or hyperopic.

Examination and Measurement of a Myopic Eye by the Direct Method.—The retina of a myopic eye is at the conjugate focus of an object situated at finite

distance (see page 99); consequently rays proceeding from the retina of a myopic eye are focused at the far point when the accommodation is relaxed (Fig. 44, C). As this far point is at finite distance—in fact, near the eye—the rays are convergent; consequently they will not be focused on the retina of an emmetropic eye unless they are made parallel by using a suitable concave glass in the ophthalmoscope. This is done by turning the wheel of the instrument and bringing concave glasses before the opening, and the weakest concave glass required is the measure of refraction (if the accommodation of both the observer's and the observed eye is relaxed).

The observer will, of course, be able, by using his accommodation, to see the fundus with a stronger concave glass than is required, but it will not then be the measure of the myopia. If the observer be a myope, and his myopia be not corrected with glasses, to ascertain the refraction of the observed eye he must deduct from the concave glass he requires the amount of his own myopia. When, for instance, the weakest concave he requires to see clearly the retina of the myopic eye is -5, and he himself is -2, then the observed eye is -3. When he is hyperopic, he must add the amount of his hyperopia—*i.e.*, when he has hyperopia of 2, and the weakest glass he requires is -5, the amount of myopia in the observed eye is -7.

The Examination and Measurement of a Hyperopic Eye by the Direct Method (Fig. 44, A).—The rays emerging from a hyperopic eye are divergent (see page 85), and as they must be made parallel for an emmetropic observer if he wish to see the fundus clearly, a convex glass, representing the amount of hyperopia, must be turned into position. If the patient have hyperopia of 4, then $+4$ must be used. The fundus could be seen clearly without a glass, by accommodation; but

then, as it would be impossible to measure the amount of accommodation used, so would it be impossible to estimate the amount of hyperopia in the observed eye.

A hyperope who is examining a hyperopic eye with the ophthalmoscope must deduct the amount of his own hyperopia from the strongest lens he requires to see the fundus with; *i.e.*, if he be hyperopic to the extent of 3, and the strongest convex glass he can clearly see the fundus with, is $+6$, the observed eye has a hyperopia of 3 D.

A myope, on the other hand, as he requires a weaker correcting glass, must add in dioptres the amount of the defect; thus, when he is *myopic* to the extent of 5, and requires no glass to see the fundus clearly, the eye that is being examined is *hyperopic* to the extent of 5. Again, when his myopia is 3, and the strength of the convex glass he can use is 2, the amount of hyperopia present in the observed eye is 5; or when he has myopia of 7, and he cannot see the fundus clearly with any glass less concave than 3, the amount of hyperopia present is $7 + (-3)$—*i.e.*, 4 D.

To summarize, we may say that if an ametrope, to see clearly the fundus of an eye with the ophthalmoscope and to estimate correctly its refraction, requires—

(1) A glass of the same kind as his own ametropia, but stronger, he must deduct the number of his own from that glass.

Example.—He has a myopia of 3, and requires -5 in the ophthalmoscope, then the error of the observed eye is -2.

(2) A glass of the same kind, but from one to ten dioptres weaker than his own ametropia, then the eye that is being examined has an ametropia of from one to ten dioptres of the opposite kind.

Example.—He has a myopia of 6, and requires -5; the refractive defect of the observed eye is $+1$. If he require -4, it is $+2$, and so on. He has hyperopia $+4$, and requires $+3$; then the refractive error of the observed eye is -1.

(3) A glass neither of the same kind nor strength, then the refraction of the observed eye is the opposite to that of the observer's, and the amount is equal to the addition of the number of dioptres of each.

Example.—He has myopia of 5, and requires + 3; the refraction of the observed eye is + 8. He has hyperopia of 3, and requires – 2; the error is – 5.

It should be borne in mind that, to insure the exact measurement of the patient's refraction by means of the ophthalmoscope, the yellow spot must be looked at. If the patient be *not* under the influence of a mydriatic, this is not always easy, for not only does the pupil contract when the examined eye is turned towards the mirror, but the light reflex from the cornea interferes very much with the view unless the electric ophthalmoscope with Marple mirror is used; and, further, the absence of any large structure, such as the retinal vessels, makes it difficult to secure the correct focus. As a rule, all that is seen at the macula is a slight stippling, produced by the irregular deposit of retinal pigment, and when this pigment is specially pronounced we get a bright ring or crescent at the fovea. This is the foveal reflex; and although it is slightly in front of the retina, the distance is so small that it can be ignored, and this foveal reflex can be focused and made use of in this manner, for ascertaining the refraction. If it cannot be used in this way, through being too faint, we must focus a small retinal vessel passing from the disc to the macula.

The beginner will find that the easiest part to focus is the temporal side of the disc, for its margin here is generally very well defined.

The Measurement of Astigmatism.—It is very difficult, if not impossible, to diagnose low errors of astigmatism by the ophthalmoscope, but an error of one dioptre or more is revealed by portions of the fundus picture being out of focus, and by our inability

to get a clear picture of all parts at the same time by any of the spherical glasses in the ophthalmoscope. Some ophthalmoscopes have cylindrical glasses fixed in them, but this is not at all necessary, as the astigmatism can be approximately estimated without much difficulty by measuring the refraction of the meridians at right angles to each other in the following manner: Focus, for instance, the vessels that pass in a horizontal direction from the disc to the macula, and note the glass in the ophthalmoscope (the weakest concave and strongest convex) that is required to give a clear definition; this will give the refraction of the meridian at right angles to the horizontal one—viz., the vertical. Then focus the vessels that pass vertically upwards and downwards from the disc; this will give the refraction of the horizontal meridian, and the difference between the two glasses (if any) is the amount of the astigmatism (if any).

When the chief meridians are not vertical and horizontal, but oblique, we can then, say, focus the vessels passing upwards and outwards from the disc, and when we have focused these vessels, if astigmatism exist, the vessels passing downwards and outwards will not be in focus, but will be either blurred or invisible, and we proceed to find the glass that is necessary to bring these latter vessels into focus, and so on. If the correcting glass be a large one, we must be careful to look through the centre, for if we look through the glass obliquely we shall get an appearance as if produced by astigmatism, which might not be present.

In estimating the refraction by means of the ophthalmoscope, as above explained, the observer should approximate his eye as much as possible to the eye that is being examined, as the value of the lens is altered by altering the distance; a concave glass is weakened and a convex glass strengthened by removal from the eye. It is for this reason that old people are often seen to wear their glasses low down on the nose, the strength of the convex glass being slightly increased. This, of course, specially refers to lenses of high power; therefore, the further away we

hold the ophthalmoscope the more shall we overcorrect in myopia and undercorrect in hyperopia—*i.e.*, the myopia of the eye being examined will be less, and the hyperopia more, than that represented by the ophthalmoscope glass.

3. **The Estimation of the Refraction by the "Shadow Test"; Retinoscopy; Skiascopy.**—Seated at a short distance from the patient in a dark room, if we throw the light on to the patient's eye by means of an ophthalmoscopic mirror, provided the pupil is normal and the media are clear, we observe the red reflex of the fundus; and if we gently rotate the mirror, the red reflex disappears, and darkness takes its place. The manner in which this darkness or shadow appears varies according to the refraction of the eye.

We will examine the behaviour of the shadow under three conditions:

1. When the observer is *beyond* the patient's far point.
2. When he is *within* the patient's far point.
3. When he is exactly *at* the patient's far point.

1. Let us suppose the surgeon *Ob* (Fig. 46, A) examining the patient *Pt* by this method, and using the plane mirror, and we will assume *Pt* to have a refractive error of over 1 of myopia. *Ob* is seated 1 metre off *Pt*, and is consequently beyond *Pt*'s far point. *Ob* reflects the light into *Pt*'s eye and observes the red reflex; and if he rotate the mirror, making the light pass, say, across *Pt*'s face from the nose to the temple, he will notice that the red reflex disappears, and that darkness takes its place, and in this example the darkness or shadow comes over the eye from the temple towards the nose—that is, in the opposite direction to the rotation of the mirror.

Let us see how this has come about. In Fig. 46, for the sake of clearness, the mirror and the light have been omitted, and only the rays proceeding from *Pt*'s fundus have been drawn.

All luminous rays proceeding from the fundus of *Pt*

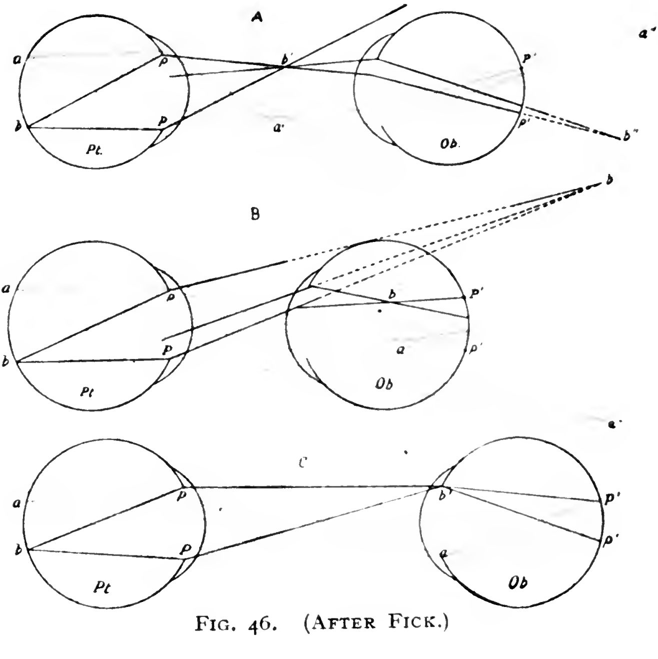


FIG. 46. (AFTER FICK.)

through the pupil *P p* (Fig. 46, A) either do not reach the eye *Ob*, or they impinge on *Ob*'s retina between *P′* and *p′*. Thus, all rays from *p*, from whatever part of *Pt*'s fundus they come, must unite at *p′* of *Ob* if they are intercepted by *Ob*'s pupil.

Let *a* be a luminous point on the fundus of *Pt* (who in this case is assumed to have a myopia of over 1), then at *Pt*'s far point, somewhere on the line between *a* and the nodal point, an aerial image *a′* of *a* will be formed. Some of the diverging rays from *a′* will reach *Ob*, and, passing through the refractive media, will unite at *a″*; but as *Ob*'s fundus intercepts these rays, a bright diffusion circle will be formed on the upper part of *P′ p′* (*Ob*'s fundus), while the lower part of *P′ p′* will be in darkness. Now, as our retinal images are projected inverted, *Ob* sees the pupil of *Pt* light below and dark above. If the luminous spot *a* descend to *b* in *Pt*, its image ascends to *b′*, and we have a bright area below in *P′ p′*, and *Ob* sees in *Pt*'s pupil a bright area passing *from below upwards*.

We thus see how in myopia of over 1 D, with the observer 1 metre from the patient, and using a plane mirror, the "shadow" moves *against* the rotation of the mirror.

2. The reverse obtains when *Ob* is *within* *Pt*'s far point. Let us suppose (Fig. 46, B) *Pt* to be hyperopic. The image of *a* will be at *a′*, but those rays that pass through *Ob*'s pupil are refracted, and meet at *a″* in front of the retina, and, diverging again, meet *Ob*'s retina at *p′* as a diffusion circle; in this case the bright area, being below, is projected inversely, and *Ob* sees *Pt*'s pupil bright above and dark below, and if *a* moves down to *b*, it will be seen that *Ob* projects the bright area moving down also. Thus, with a plane mirror, if *Ob* be within *Pt*'s far point, the shadow moves *with* the mirror; if *Ob* be seated 1 metre off *Pt*, this will occur in hyperopia, emmetropia, and myopia of less than 1 D.

3. Lastly, let us consider what happens when *Ob* is exactly at *Pt*'s far point, which, of course, occurs if *Ob* be seated 1 metre off *Pt*, who has a myopia of 1 D (Fig. 46, C). The illuminated point *a* has its image *a'* exactly on the pupil of *Ob*, and as the ray *p a'* is refracted to *p'*, and the ray *P a'* to *O'*, the entire area *P' p'* is illuminated, and the entire pupil of *Pt* appears illuminated to *Ob*. Movement of *a* to *b* produces no effect; the area *P' p'* is still illuminated; but when the luminous point on *Pt*'s retina passes below *b* or above *a*—that is, outside the area *a b*—it is focused on *Ob*'s iris, and no rays reach *Ob*'s retina; consequently *Ob* sees the pupil *P p* becoming *suddenly* dark, and there is *no* moving shadow. This point, when the observer's eye is exactly at the patient's far point, is called the " point of reversal," and the whole principle of retinoscopy is to find this point. In myopia *Ob* can move nearer to or further from the patient, and measure off the distance of the point of reversal, and so obtain the refraction of that particular meridian; but in hyperopia this cannot be done, so that the best method is to work always at one fixed point—say 1 metre—and make the patient artificially myopic, if hyperopia or emmetropia exist, by placing before *Pt*'s eye convex glasses; if he be myopic, make him less myopic by using concave glasses.

Let us now examine a patient. The patient's eyes should (if possible) be under the influence of a cycloplegic, which not only gives us a dilated pupil and makes the retinoscopy easier, but insures the relaxation of the ciliary muscle, which of course is essential. The patient should be seated in a dark room, with the light above or on one side of his head and slightly behind, so that no rays can reach the eye except from the mirror. We provide ourselves with a set of test lenses and a trial frame, and seated, say, 1 metre off the patient, we reflect the light by means of the plane mirror into the patient's eye, directing him to look at the sight-hole of the mirror.

Suppose we are examining the right eye, and rotate the mirror so that the light passes across from the patient's nose to the temple, and suppose we notice that as the light leaves the pupil a dark shadow takes its place, passing across in the same direction—*i.e.*, from the nose to the temple—we know from Fig. 46, B, that we are *within* the patient's far point, and that we are dealing with a hyperope or emmetrope, or myope of less than 1. Let us place in the trial frame +2: we find, say, that the shadow is still moving *with* the mirror; we are therefore dealing with hyperopia. Put up +4: the shadow now moves against the mirror, which means we are outside the patient's far point; put up +3, and we find on rotating the mirror that the pupil becomes suddenly dark, and there is no shadow following with the rotation, or passing against it. This, then, is the point of reversal. We have found the point of reversal with a +3 lens, seated 1 metre from the patient, which means that this meridian has a myopia of 1 with a +3 lens in front, and, deducting 1 from 3, leaves us 2 as representing the hyperopia. If the patient had been emmetropic in this meridian, a +1 lens would have given us the point of reversal at 1 metre.

If the patient's eye have a myopia of over 1, when we are seated 1 metre off we must be outside his far point, whatever the amount of myopia, and the shadow moves " against " the plane mirror, and that glass which gives us the point of reversal represents the amount of myopia of that meridian with −1 added if we are seated 1 metre off (or −2 added if seated 50 cms. off, or −·5 added if 2 metres off)—that is, if −5 gives the point of reversal, −6 is the amount of myopia. Some surgeons always aim at reversing the shadow—that is, they purposely go beyond the point of reversal, and slightly overcorrect. This is quite safe if allowance be made for the overcorrection.

In the examples, we have been ascertaining the far

point of one meridian only—viz., the horizontal; we must now proceed to examine the meridian at right angles—viz., the vertical—and if the same glass give us the point of reversal, we know that no astigmatism is present; but if there be a difference, that difference represents the astigmatism. When the astigmatism is great, and especially when one meridian is emmetropic or made emmetropic, the light is seen to pass across as a bright band (Fig. 47), and sometimes two bright bands are seen with a dark band in the centre, and as the bright bands approximate each other, the central dark band disappears, and one bright band remains. This has been called the "scissor movement."

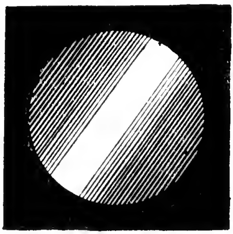


FIG. 47.

In oblique astigmatism, of course, the meridians are not vertical and horizontal, and when the astigmatism is marked, the appearance of the shadow is very characteristic, and a bright band is seen passing obliquely across the pupil, although we may be moving the mirror horizontally or vertically (Fig. 47). Suppose we are dealing with oblique mixed astigmatism, and, rotating the mirror horizontally, we observe a bright band followed by a shadow passing obliquely across the pupil "with" the plane mirror, we note the axis of this bright band, and also note that the meridian is hyperopic; if we then rotate the mirror at right angles to this bright band, we find that the shadow passes against the move-

ment of the mirror, showing that this meridian is myopic. Suppose the point of reversal of the horizontal oblique meridian is obtained by +3, and that of the vertical by −1, by this we know that the refraction of the horizontal meridian is +2, and that of the vertical meridian is −2, and there is therefore a total astigmatism of 4.

The greater the ametropia, the nearer is the far point to the eye, and it is of great practical importance to remember that, the greater the ametropia, the less distinct is the shadow and the slower it moves; and as we approach the point of reversal by using correcting glasses, we obtain an increasingly defined shadow which

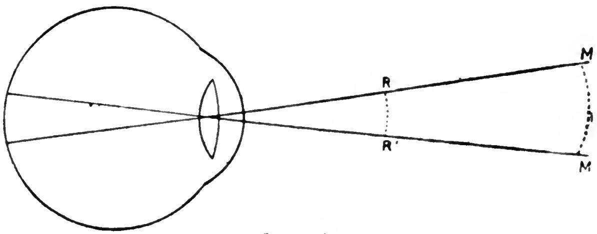


FIG. 48.

moves more and more rapidly. We can thus, at once, make a rough estimate of the degree and kind of ametropia.

In Fig. 48, if R be the far point of the myopic eye, on rotating the mirror, the shadow moves from R to R′; but if the myopia be less, and the far point at M, the shadow will have to describe the larger arc M M′ in the same time—that is, it will move more quickly.

In the same way, if the far point of a hyperope be at R (Fig. 49), the shadow will move more slowly than when the hyperopia is less and the far point at H.

Some surgeons use the plane mirror at a distance of 4 metres always, and as only ·25 D has to be deducted from the retinoscopy, this small amount can be ignored,

and the point of reversal of a meridian represents the measurement of that meridian.

When the surgeon is nearer than 1 metre, he must, of course, deduct more than 1. For instance, suppose at 33 cms. the point of reversal of a meridian is obtained with +5, as his far point is $\frac{1}{3}$ metre off, we have made the patient artificially myopic to the extent of 3, and we must deduct this from 5; therefore 5 - 3 (that is, 2) represents the hyperopia of this meridian.

Many surgeons still use the concave mirror. The mirror should have a focus of 25 cms., and the observer should be seated a little over a metre from the patient. The movement of the shadow is the reverse of that which takes place with the plane mirror—that is, the shadow

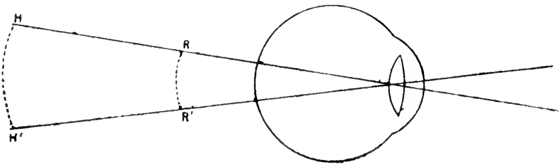


FIG. 49.

moves "with" the mirror in myopia of over 1, and "against" the mirror in myopia of less than 1, and in hyperopia and emmetropia. This is easily understood if we remember that with a concave mirror the rays of light converge to the focal point of the mirror, and then cross and diverge; consequently the image thrown on a screen by a concave mirror is inverted.

[If we reflect a lighted candle on to a dark screen by a concave mirror held further from the screen than its focal distance, and if we then focus the divergent rays with a convex lens, we shall get an erect image, because the rays have been twice inverted, whereas with a plane mirror used in the same manner we obtain an inverted image, because there has been only one inversion.]

If the observer be not emmetropic, he should wear his correcting glass. This, of course, especially applies if

he be myopic. If he be hyperopic, he may correct his defect by accommodation if he choose. The point to be remembered is, that to practise retinoscopy accurately the observer requires a normal acuity of vision. He

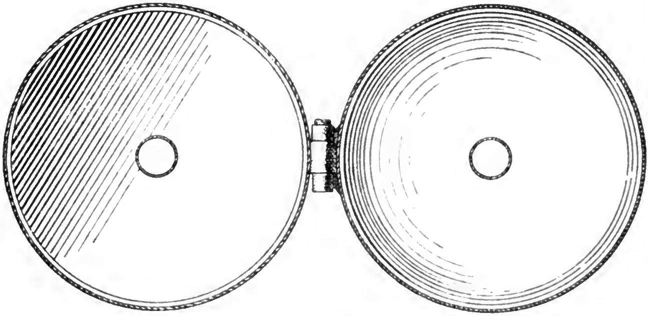


FIG. 50.

may accommodate as much as he likes, as it does not affect the result.

As the point of reversal is more definite when the shadow moves *with*, it is not a bad plan to use a plane

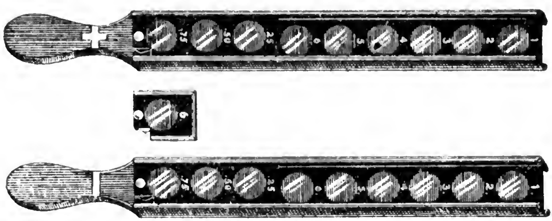


FIG. 51.—MARPLE'S SKIASCOPES.

mirror when estimating hyperopia, and a concave mirror when estimating myopia. These two mirrors can be hinged together, and thus each mirror is the handle and cover of the other (Fig. 50).

Marple's skiascopes (Fig. 51), made by Meyrowitz of New York, are very useful, and obviate the necessity for keeping a

separate test case in the dark room; they are designed to be held by the patient before the eye during retinoscopic examination. Each contains a series of six lenses, ranging from 1 to 6 dioptres, plus and minus respectively. In addition to these lenses there is on one side a movable slide containing a 6 D lens, which can be quickly slipped up over the other lenses one after the other, making further combinations from 7 D to 12 D. To determine smaller errors within 1 D, a slide containing three lenses ·25, ·50, and ·75 D, respectively, is placed on the other side, and can easily be brought before the other lenses. On the skiascope containing the plus lenses the movable slide carries minus fraction lenses, and *vice versa*.

CHAPTER VI

HYPEROPIA

Hyperopia or Hypermetropia.—The hyperopic eye is the undeveloped eye in which, with accommodation at rest, parallel rays come to a focus beyond the retina (Fig. 20, H), and only convergent rays focus on the retina; but as in Nature all rays are either parallel or divergent, it follows that the hyperopic eye at *rest* sees everything indistinctly.

Rays coming from a point on the retina diverge, and, on passing through the dioptric system, emerge from the normal eye as parallel rays. In hyperopia, although they are not so divergent as they were before refraction, they still diverge if the eye be at rest, and therefore never come to a focus in front of the eye; but when prolonged backwards, they will meet at a point behind the eye—the *punctum remotum*. This punctum remotum of the hyperope is therefore not the actual focus of the distant rays, but the virtual focus, and is represented by the negative sign $-R$ (Fig. 52).

It will be seen from Fig. 52 that the more divergent the rays are in front of the eye, the nearer will their "backward prolongation" focus; hence the nearer $-R$ is to the eye, the higher will be the hyperopia.

This is the same as in myopia—viz., the higher the myopia, the nearer is R to the eye; but the difference is that in myopia R is in front of the eye, and in hyperopia it is an imaginary point behind the eye.

Thus, the degree of hyperopia is in inverse ratio to the distance of the punctum remotum. In myopia this point can be measured directly, but in hyperopia it can only be done indirectly by employing convex glasses.

Suppose the punctum remotum of a hyperope is 33 cms. behind the retina. We have seen that a convex lens whose focal point is 33 cms. is 3 D—that is, such a lens has the power of converging parallel rays to a point 33 cms. on the other side of the lens, and conversely, rays diverging from a point 33 cms. in front of

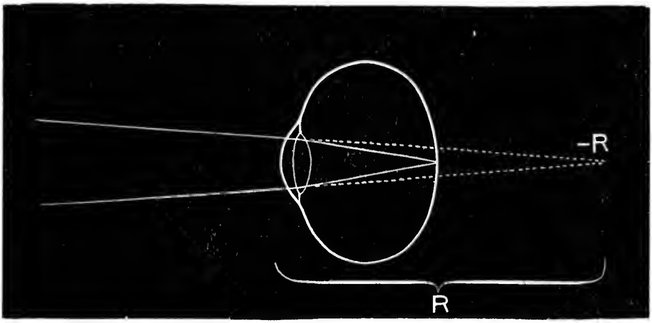


FIG. 52.

Showing the punctum remotum of a hyperopic eye.

such a lens become parallel on passing through. If this lens be put in front of the eye of this hyperope, it will so act that, assisted by the dioptric system of the eye, it will cause parallel rays to focus *on* the retina. Hence the measurement of hyperopia is that convex lens which enables the hyperopic eye, at rest, to see distinctly objects at a distance, and the focal length of such a lens represents the distance of the virtual far point from the eye. In the above example it was found that +3 was this lens, and we accordingly say that this eye has a hyperopia of 3.

A hyperope differs from a myope in that he can correct his defect up to a certain point; he can by accommodation produce the same effect on parallel rays as if a convex glass were placed in front of the eye. This apparent advantage brings with it many disadvantages—viz., all the troubles incident to eyestrain.

The hyperopic eye is never at rest; it has to accommodate for distant as well as for near objects. The emmetrope's ciliary muscle is at rest when he is looking at any object 20 feet off, or beyond, but the hyperope's

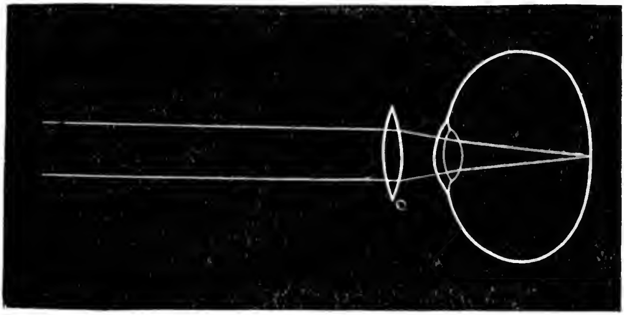


FIG. 53.

Showing parallel rays focused on the retina of a hyperopic eye by means of a convex lens.

eye is never at rest if he attempt to see distinctly; and, moreover, when he wishes to look at a near object, he starts with a deficit, which deficit is the amount of accommodation he required for distant vision. Thus, a hyperope of four dioptres, with five dioptres of accommodation, can focus distant objects clearly, but then he has only *one* dioptre left for near vision; this will only bring his near point to 1 metre from the eyes. Again, take a hyperope of two dioptres, with five dioptres of accommodation: he has only three dioptres available for accommodation for near objects;

this brings his near point to 33 cms., but he is using the whole of his accommodative power for this, and it is impossible for him to do this for long without fatigue, and so we get all the symptoms of eyestrain.

We have seen that in hyperopia a = p − (− r) = p + r (page 35), therefore p = a − r ; in other words, the

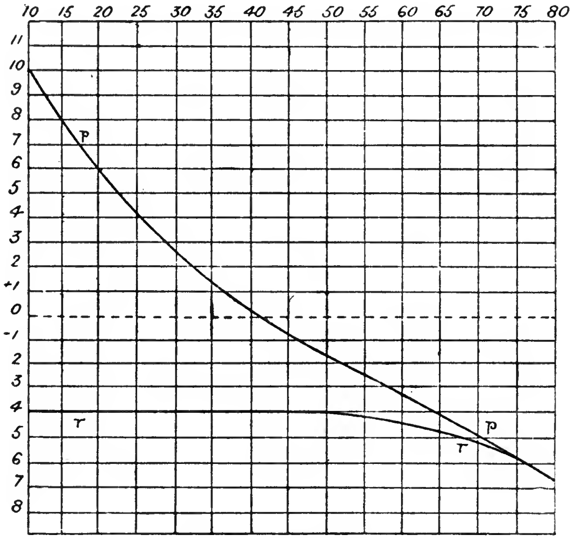


Fig. 54.*

Showing the range of accommodation of an uncorrected hyperope of 4 D at different ages.

The numerals above represent years, those on the left, dioptres. The line *p p* represents the curve of the punctum proximum, and the line *r r* that of the punctum remotum.

available amount of accommodation is represented by the total accommodation less the amount required to correct the hyperopia, so that although, as we have

* As Donders' diagrams are still universally used I have retained them, but I would refer the reader to Chapter IX. (Presbyopia).

seen, age for age the hyperopic eye has the same total amount of accommodative power as the normal eye, it has less to use for near vision, if uncorrected. In Fig. 54 the amount of available accommodative power in the uncorrected hyperope of 4 D is represented by the number of dioptres between *p* and the zero line; thus, at the age of 30 we find only two and a half, representing 2·5 D of accommodative power, because, although he has 6·5 D total power like the emmetrope, 4 of this is used up to correct his defect. At the age of 40 we see that *p* crosses the zero line; in other words, all available power is lost. He has 4 D left, but this is used up in correcting his defect. Beyond this age he loses still more accommodative power, and this means that he cannot even correct his defect; in other words, he cannot obtain clear images of anything far or near.

This condition will obtain, of course, at an earlier age if the hyperopia be higher. Thus, a hyperope of 10 D at 25 has only 8 D accommodative power, and consequently sees everything indistinctly. Such persons often approach their eyes very near their work in order to obtain larger retinal images, and an erroneous diagnosis of myopia is liable to be made.

The Varieties of Hyperopia.—The hyperopia which is at once recognized, the patient confessing to improved vision with a convex glass, is called manifest, and this manifest hyperopia (Hm) is expressed in amount by the *strongest* convex glass the patient accepts. For instance, a patient sees $\frac{6}{9}$, but with +1 in front of the eye $\frac{6}{6}$: +1·5 makes the letters hazy, then +1 D = Hm.

Again, when the defect is hidden by the patient using his accommodation and obtaining perfect distant vision, hyperopia is present if he accepts a convex glass and the total manifest hyperopia is represented by the strongest convex glass with which he can see

equally well as with the naked eye. (It should be noted that neither the emmetrope nor the myope will, under any circumstances, accept even the weakest convex glass for distance.)

The latent hyperopia is the additional hyperopia, which shows itself when the accommodation has been relaxed by a cycloplegic. If the patient quoted above, when under atropine, see $\frac{6}{6}$ only when $+3$ is used, in his case $+2$ represents the latent hyperopia (Hl), the total hyperopia (Ht) being the sum of Hm and Hl. Hm + Hl = Ht.

Thus:

Total Hyperopia (*Ht*)	Latent H. (*Hl*)	Only revealed under a cycloplegic.
	Manifest H. (*Hm*)	*Absolute* (Hma), which no amount of accommodation can correct, represented by the weakest convex glass.
		Facultative (Hmf), when distant objects can be clearly seen with or without convex glasses, represented by the difference between the strongest and weakest convex glass.

The want of harmony between the accommodation and the convergence is a constant cause of eyestrain in uncorrected hyperopia. We have seen (page 48) that in normal vision, the two eyes converging for a point 1 metre off, form a metre angle, and use 1 D of accommodation. Eyes converging for a point 50 cms. off have to converge 2 metre angles and accommodate 2 D, and so on. Now, a hyperope of 2, when looking at a point 33 cms. off, is using $\frac{100}{33}$—*i.e.*, 3 D added to the correction of his hyperopia—viz., $3+2=5$ D; but he is only converging 3 metre angles instead of 5, consequently he is using 2 D of accommodation in excess of convergence.

Nature has endowed many hyperopes with the power of increasing their accommodation, *to a certain extent*, without varying their convergence; this faculty is the

result of "nerve education." We shall see when dealing with myopia that the same thing occurs, only in this case it is the convergence that is used in excess of the accommodation. There is a minimum amount of effort when convergence and accommodation work harmoniously together, as it were supporting each other; but when one is used in excess of the other, it has to work unaided and alone, and strain is liable to ensue.

Many hyperopes never become capable of using their accommodation in excess of convergence, and therefore they are less likely to suffer from strain (although the unconscious effort to do so may induce it); but a worse evil befalls them—they lose binocular vision, and squint. A hyperope, under these circumstances, finds himself in the following dilemma: if he wishes to see binocularly, he must use less accommodative power than he requires to see distinctly; or, if he wishes to see distinctly, he must sacrifice binocular vision, which ends in squint. He must choose between distinct vision and binocular vision. Distinct vision is more craved for, and more useful, than binocular vision, especially if the latter be not quite perfect, owing to one eye being more defective than the other; consequently, he sacrifices binocular vision, and squints, and the eyestrain ceases* (see Strabismus, page 184).

Conditions causing Hyperopia—1. *Axial Hyperopia.*—This is the commonest form, and is the condition of most eyes at birth. It is due to the shortening of the antero-posterior diameter of the eye, and may be due to a flattening of the globe or to a general diminution in size. Roughly, every 3 D of hyperopia represents a diminution of 1 mm. of the axial line.

This condition is due to an arrest of growth of the eye, and is often associated with arrest of growth of the neighbouring bony parts; thus, the face of a hyperope often shows want of relief.

* Donders called this form of hyperopia *relative*.

The tendency is for hyperopic eyes, at birth, to grow towards the normal and even to become myopic; but after 50, owing to the increase in size and the flattening of the lens with age, there is a tendency for all eyes to become hyperopic as life advances; this is called *acquired hyperopia* (see page 145).

2. *Curvature Hyperopia :* due to a lack of convexity of the refractive surfaces; it is generally associated with astigmatism (see page 119).

3. *Index Hyperopia :* due to diminution in the index of refraction of the media.

4. Hyperopia may be due to absence of the lens (*aphakia*), or its total or partial dislocation.

5. Tumours or exudations causing *advance of the retina* in the eye will cause hyperopia.

Symptoms.—It is the facultative hyperopia which the patient can correct, and thus more or less conceal at will, which is one of the most common causes of eyestrain, and the reason is very apparent.

In absolute Hm, vision is never acute, and the patient makes no attempt to strain his accommodation, because he finds the result of little or no use.

In relative Hm, it has been seen that only monocular vision can be acute, and that eyestrain generally ceases when the squint appears.

Patients with facultative Hm are most frequently quite unaware that they are suffering from any defect of the eyes; they can see well at a distance, their near vision is as good as they want, they have no idea that the headaches that come on after near work are caused by eyestrain, and they will in all probability be treated for all manner of diseases before the real cause is discovered. It is true that when this eyestrain lasts long, signs of inflammation will often show themselves in the eye and its appendages, such as conjunctivitis and blepharitis, and lead the patient to the oculist; but even he may miss the true cause unless he make it

a rule to examine, under atropine, the eyes of all young people suffering from chronic inflammation of the lids or conjunctiva, they being especially the subjects of this condition.

The facultative hyperopia of the young becomes absolute after middle life.

Although it is quite possible to suffer from facultative Hm, and pass through youth without any symptoms of eyestrain, sooner or later they will appear. Good health, plenty of outdoor exercise, and not too much application to books, will ward off eyestrain for a long time; but in these days of examinations the day must surely come when the young student must "cram," when he must read four or five hours a day by artificial light, when he must do more work and take less play—in other words, when he must use his muscles of accommodation for a much longer time. As a result, after a few hours' reading, his head aches, his eyes pain, and the type appears to run together. Many such cases may occur from simple overwork in emmetropes, but there is little doubt that many a young man has broken down reading for his "Tripos" simply because he is hyperopic and has overstrained his eyes. Patients often suffer from eyestrain for the first time through taking up German or Hebrew; the fine strokes that have to be recognized in order to distinguish the different letters (especially is this so in Hebrew) put an extra strain on the accommodation, and if the eye start with a deficit, as it does in hyperopia, eyestrain is sure to ensue.

If symptoms of eyestrain occur among the upper classes who suffer from this form of hyperopia, how much more must they occur in those who spend their lives at close work, in badly lighted and badly ventilated rooms, with little or no outdoor exercise and often insufficient food. Yet the large body of seamstresses and compositors, who find their way to the out-patient

room of an ophthalmic hospital, are only a small fraction of the number who really want relief, but do not recognize it because they see well without glasses. Those who do come for advice generally tell the same tale; they are at work, say, from eight in the morning till eight or ten at night, and towards evening they complain that their vision becomes less acute, and their eyes and head ache. It is but natural; their ciliary muscles have been working at high pressure all day, and in their way have done as much work as the leg muscles would in a thirty-mile walk. Surely in an emmetropic eye we should expect fatigue under such circumstances; how much more, then, in a hyperopic eye!

With advancing years the latent hyperopia becomes gradually and finally, about the age of 40, entirely manifest, and with the diminution of accommodation range the hyperope necessarily becomes prematurely "presbyopic." As might be expected, symptoms of eye-strain are much more common in presbyopes who are hyperopic than in those who are emmetropic or myopic.

One of the results of *eyestrain* in young hyperopes, or in those who have to make great efforts to see small objects, as watchmakers, is **spasm of the ciliary muscle,** whereby vision is accommodated for near objects, and the patient rendered artificially myopic (see page 109). This spasm is usually accompanied by a contracted pupil from associated spasm of the sphincter of the iris, both conditions being caused by direct or indirect irritation of the third nerve (see page 201).

Hyperopic headache is often accompanied by twitchings of the eyelids.

Besides the many symptoms of eyestrain already described, the special indications of hyperopia are—

1. Spasm of ciliary muscle, often producing apparent myopia.

2. Sudden failure of the ciliary muscle from fatigue, causing obscurations of vision.

3. Convergent strabismus.

4. Apparent divergent strabismus.

The angle gamma is larger—*i.e.*, the angle formed by the visual and optic axes is increased, which causes apparent divergence of the axis of the cornea (see page 187).

There are also certain physical signs noticeable in hyperopes.

The eye is flatter than normal and often markedly smaller; if the eyeball be turned strongly in or out, the equatorial region presents a much sharper curve than in the normal or myopic eye, showing its shortened axis.

The cornea is often smaller than usual. The face is sometimes flat-looking.

The ciliary muscle of a hyperope is always larger than normal; this is especially marked in the annular muscle of Müller, and is due to excessive use.

The Diagnosis of Hyperopia by Examination.—1. Vision is improved by, or is as good with, convex glasses.

2. Retinoscopy gives a shadow moving " with " with a plane mirror, and a reverse shadow with a concave mirror, and the more defined the shadow and the quicker its movement, the lower the hyperopia.

3. The indirect ophthalmoscopic examination shows an image of the disc larger than normal, and diminishing on withdrawing the lens from the eye.

4. In the direct ophthalmoscope examination, if the observer's accommodation be relaxed, a convex glass is required in the ophthalmoscope to obtain a clear image of the fundus. If the hyperopia be high, the mirror alone, a short distance from the eye, shows an erect image of the fundus moving *with* the observer.

The Influence of Age on Hyperopia.—See Presbyopia, page 142.

Treatment.—Up to 6 years of age atropine should be applied to the eyes for *at least* three days twice a day before the examination.

During this period of life the eye has not fully developed, most children have a certain amount of hyperopia, which should only be corrected if high in amount, or if *strabismus* be present.

As the examination before the type at this age is of no practical value, the surgeon has to depend on the result of his retinoscopy.

The glasses ordered should be weaker than the atropine estimate. Suppose the retinoscopy, under atropine, gives +4 at a metre, this would mean +3 before the type if the patient can read, and the glass ordered should not be stronger than +2. It will be found that when the error is greater, more than +1 must be deducted from the atropine correction.

The correction of hyperopia, when adopted with those who have developed convergent strabismus, has often the happiest results, for the squint may be cured without resorting to an operation, and the result is in direct ratio to the youth of the patient. Moreover, these are the hyperopes who can most readily be made practically "emmetropic," and therefore get the greatest gain from the glasses; for their very defect, the squint, shows that they have been unable to dissociate their accommodation and convergence. It is this habit of using their accommodation in excess, which has led to hypertrophy of the ciliary muscle, which prevents many hyperopes from taking full correction. They cannot overcome the habit, and naturally the older the patient, the greater the probability is there of this being possible. In such cases a much weaker convex glass must be given at first, and its strength increased later.

When the amplitude of accommodation is great, the patient will probably prefer a weaker glass than we wish to give, and *vice versa.* When the hyperopia is small in amount, and equal in the two eyes, and there is no strabismus, it is unwise to order any glass.

From ages 6 *to* 15 the atropine should be applied to the eyes twice daily for two days before examination.

By this time the eye should be emmetropic, and as the child is entering the active period of school career, the hyperopia should be corrected, unless *very small* in amount, and even then when associated with astigmatism or anisometropia, or both.

At this period we must recognize the "personal equation." Some patients will stand a fuller correction of their defect than others.

After ascertaining the amount of error under atropine, we must, whenever possible, arrange for a final examination before the test types, when the effects of the cycloplegic have passed off. We should prescribe the fullest correction of the error the patient will accept, consistent with good vision. For instance, under atropine a child of 12 reads years $\frac{6}{6}$ with +3. When the effects of the atropine have passed off, deducting +1 for the atropine, we find that +2 gives $\frac{6}{9}$ hazily, and that it is only when we reach +1·25 that $\frac{6}{6}$ is clearly read. This is the correction we order, with a cylinder correcting the astigmatism, if present (see page 138).

We must remember that such a patient did not come to us for improvement in vision; he probably read $\frac{6}{6}$ quite well, and if we insist on his wearing a correction which makes his distant vision worse, he will seize every opportunity of *not* wearing the glasses.

When the hyperopia is slight (say only 1·75 or 2 under atropine), equal in the two eyes, and unassociated with astigmatism or strabismus, glasses *are not necessary*.

From ages 15 *to* 25 *or* 30 atropine is the best cycloplegic, but in a large number of cases we have to be content with homatropine, because atropine necessitates too long a period of rest from work. Glasses should not be prescribed until the patient has recovered from the effects of the cycloplegic, and then the fullest correction

of the error that the patient will accept, consistent with clear vision, should be ordered to be worn always.*

In high hyperopia, especially in cases where the patient will only accept a very partial correction of the error, it is advisable to give the full atropine correction, as special near-work glasses, for use by artificial light.

From ages 30 *to* 45 homatropine should be used as the cycloplegic, and in the case of patients with high hyperopia, or when the smallest fear of glaucoma is present, one drop of eserine (2 grains to the ounce) should be put into the eyes when the examination is finished.

The treatment is the same as for younger patients.

A larger proportion of the correction will be accepted, and the older the patient, the more necessary is it to give the full cycloplegic correction for near work.

Over age 45 no cycloplegic is necessary, as all the hyperopia has by this time become manifest.

The strongest convex glass the patient will accept must be prescribed, and as the presbyopic period has arrived, a still stronger glass will be required for reading, and the two are best prescribed in one glass in the form of invisible bi-focals (see Presbyopia, page 151).†

* When the patient cannot return for a final visit, glasses correcting the whole of the manifest, and about one-third of the latent hyperopia, may be safely prescribed. (Manifest hyperopia is expressed in amount by the strongest convex glass the patient accepts when not under atropine. Latent hyperopia is the additional hyperopia which is revealed under atropine.)

† It is important to remember that hyperopia tends to decrease towards emmetropia. A child may be hyperopic to the extent of 2 D, and as the growth and development of the different parts of the body proceed, the flatness of the eye may disappear, and by puberty the eye may have become emmetropic. For this reason it is necessary to re-examine the eyes of children at least once a year, in order to make sure they are not wearing too strong a convex glass, which would induce an artificial myopia, which in turn might lead to real myopia. This tendency for the eye to grow normal is often interfered with by the presence of eyestrain; hence one of the benefits derived from glasses in young children is the increased chance of the eye improving and growing to the normal shape, and the possibility of discontinuing the use of spectacles.

CHAPTER VII

MYOPIA

Myopia (*μύειν*, to close, *ὤψ*, the eye, from the habit of myopes to partially shut the eyes in order to lessen the circles of diffusion), or short-sight, is a condition of the eye in which the retina is situated behind the principal focus (Fig. 20, M), and only divergent rays from a near point (Fig. 55), or parallel rays made divergent by a concave glass (Fig. 56), can come to a focus on the retina.

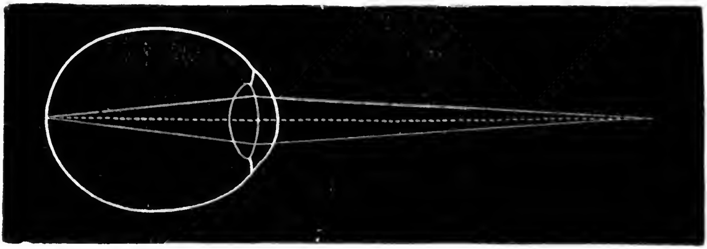


Fig. 55.

The retina of a myopic eye is the conjugate focus of an object situated at a short distance in front of the eye, or, in other words, the punctum remotum of a myope is always at a definite distance (less than 6 metres), the distance being measured by the amount of myopia. Thus, a myope of 1 has his far point 1 metre from the eye, a myope of 2 has his far point $\frac{1}{2}$ metre, or 50 cms., and a myope of 5, 20 cms., from the eye.

A myopic eye sees distinctly distant objects (when accommodation is relaxed) with that concave glass whose focal length is equal to the distance of the far point from the eye, and the converse is true: the measurement of myopia is that concave glass with which the myopic eye sees distinctly objects at a distance, and its focal length is equal to the distance of the myope's far point from the eye. If the accommodation be relaxed, the strongest concave glass is the measure of the myopia.

We can ascertain the punctum remotum of a myope directly by measuring the furthest distance at which he

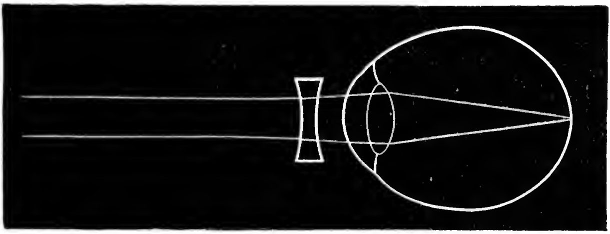


FIG. 56.

can see objects distinctly; thus, if such a spot be 2 metres from the eye, this is R, and its expression in dioptres is $r = \frac{1}{2}$ or $\cdot 5$, hence the myopia $= -\cdot 5$.

Myopia may be produced in the following ways:

1. By elongation of the axis of the eye—**axial myopia.** This may be due to—

(*a*) General elongation of the eye—**typical myopia.**

(*b*) Localized protrusion of the sclerotic, particularly at the posterior pole—**staphyloma.**

2. By increase of the refractive power of the eye—**refractive myopia.**

This may be due to—

(*a*) Increase in curvature of the cornea, as in myopic astigmatism.

(*b*) Increase in the curvature of the lens—

(*α*) In spasm of the accommodation.

(*β*) In luxation of the lens.

(*c*) Increased density of the lens, as at the beginning of senile cataract.

3. A combination of 1 and 2, as in **conical cornea,** when elongation of the axis and increase in the curvature of the cornea coexist.

Thus, we see that typical myopia is due to an elongation of the antero-posterior diameter of the eye, and every dioptre of myopia represents a lengthening of this axis by about $\frac{1}{3}$ mm.

The punctum remotum and punctum proximum of a myope are ascertained according to the methods already given.

The punctum proximum is nearer the eye than in emmetropia, and the higher the myopia the nearer it is.

As r has a positive value in myopia, the amplitude of accommodation is the difference between p and r; thus $a = p - r$.

The Influence of Age on a Myope.—See Presbyopia, page 144.

The diagram (Fig. 57) represents the amplitude of accommodation of a myope of 3 D at the different ages. The line p begins at the figure 17, showing that at the age of 10 the near point is 6 cms. from the eye; therefore $a = \frac{100}{6} - 3 = 17 - 3 = 14$ D. At 30 years of age $p = 10$ D, and P is 10 cms., while R is still 33 cms. on the positive side, $a = 10 - 3 = 7$ D.

At the age of 55 r begins to curve downwards, and reaches the zero line at 80, so that at this age the myope of 3 has lost all his myopia; p and r unite (showing that all accommodation is lost) at the age of 75.

The Relation between Accommodation and Convergence.—A myope of 5 D can see a point 20 cms. from the eye without using his accommodation, but he

must converge to 5 m.a. in order to see binocularly. As a compensation for the visual defect, most myopes have the power of using their convergence in excess of their accommodation, just as a hyperope has often the power of using his accommodation in excess of his convergence; but, it has been shown (page 91), they both have to pay

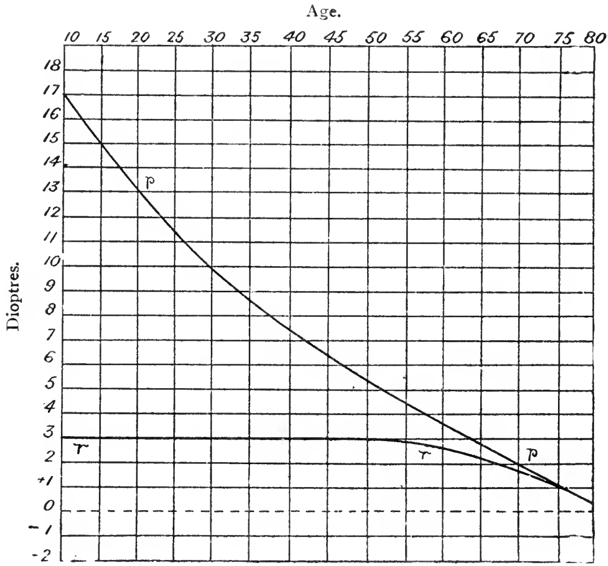


FIG. 57.*

Showing the range of accommodation of an uncorrected myope of 3 D at different ages. (Donders.)

a penalty for this, the liability to strain always being greater when either effort is used in excess of the other. The "fusion supplement" must be greater than the emmetropia, and *the greater the "fusion supplement" the greater the fatigue to the internal recti;* the fatigue leads to "insufficiency" of the muscles, and matters

* See note, p. 88.

are made worse. But it is not only the *excess* of convergence, but the *excessive* convergence that tends to produce strain and fatigue of the internal recti. The uncorrected myope sees nothing distinctly beyond his far point, and when he wishes to see clearly he must bring everything within that point; for instance, an emmetrope wishes to know the time by the clock: he can see the clock across a room, but the myope must go up to the clock and bring it within his far point; and, moreover, the incentive to use this remedy is great because the remedy is perfect. A high hyperope has the same difficulty with distant objects, but he has not the same remedy. Naturally, the greater the myopia, the nearer is the far point, and the greater is the convergence strain.

A myope requires more convergence of the visual lines because vision takes place closer to the eyes, and, as Donders has shown, precisely in myopia is this for two reasons more difficult—first on account of impeded movements, due to the altered shape of the eyeball, which becomes ellipsoidal in form, and which has to move in a cavity of similar shape; and, secondly, on account of the altered direction of the visual lines, the angle γ (angle formed by the visual and optic axes) being smaller than in emmetropia or hyperopia (see page 187). If a myope cannot dissociate his accommodation and convergence, he has the same difficulties as a hyperope: he can either see distinctly, but sacrifice binocular vision to remove the diplopia, or he can use his accommodation when he does not require it, and see indistinctly.

From the observations of Donders, Nagel, and Landolt, we find that the relative amplitude of accommodation and convergence (see page 52) vary considerably, not only according to the refractive error, but also in different individuals with the same error. There is a tendency for the accommodation to adapt itself to the altered state of refraction, hence most myopes can

converge in excess of their accommodation; and when the myopia increases, the excess of convergence over accommodation also increases.

The Causes of Myopia.—Although myopia is hereditary, it is, with few exceptions, not congenital. Almost all eyes are hyperopic at birth.

The savage is rarely myopic: it is civilization that is responsible for it. The necessity for constantly adapting the eye for near objects means undue convergence.

Myopia generally first shows itself from the age of 8 to 10, when school work begins in earnest—that is, when convergence is first used in excess—and there is no doubt that excessive convergence is mostly responsible for the development of myopia. The overused internal recti constantly pulling at the sclerotic (assisted by the pressure of the other muscles) tend to lengthen the antero-posterior diameter of the eye, becoming then the most potent factor in the causation of myopia, and as this lengthening of the antero-posterior axis necessitates still greater convergence, a vicious circle is produced, and the myopia tends to increase.

The hereditary character of myopia is explained by the existence in such eyes of an " anatomical predisposition " to myopia. The sclera is unusually thin, and consequently less able to resist the pull of the internal recti, and the relative position of the recti and the position of the optic nerve, both of which may be hereditary, may be factors in the production of this defect.

Anything which causes young subjects to approach their work too near the eyes may be the starting-point of myopia. Bad illumination, or the light coming from the wrong direction (for instance, in front), or defective vision produced by corneal nebulæ, or lamellar cataract, etc., all necessitate over-convergence in order to obtain clearer images, and myopia may be produced.

It is interesting to note that when the work is approached very near the eye, but convergence is not used,

as in the case of watchmakers, who habitually use a strong convex glass in one eye, there is no special tendency to myopia.

Symptoms and Diagnosis of Myopia. — (1) Distant objects are seen indistinctly, because parallel rays focus in front of the retina and cross and form diffusion circles on the retina, and the higher the myopia the larger the diffusion circles; these are reduced, commonly, by the myope "screwing up" his eyes, and in later life by the contraction of the pupils.

(2) Near objects are seen distinctly, and the near point is much nearer than in normal eyes.

(3) Acuteness of vision is often lowered, and in high myopia this is invariably the case, because the stretching of the eye leads to atrophic changes in the retina and choroid.

(4) The presence of convergence insufficiency and latent divergence (diagnosed by the Maddox test, page 44) for distant and near objects, often becoming manifest later, and ending in divergent strabismus.

(5) An apparent convergent strabismus due to the angle γ being negative (page 187).

(6) Many of the symptoms of eyestrain, but not so frequent or so marked as in hyperopia (see Heterophoria, page 171).

(7) Spasm of the ciliary muscle, which apparently increases the amount of myopia, so that young subjects will choose a stronger concave glass than they require.

(8) A prominence of the eyeball is sometimes noted in high myopes, but is not always present. A dilated pupil and dreamy stare are sometimes present.

(9) Muscæ volitantes are often complained of. These are probably due to the indistinct vision allowing the vitreous to be seen against a hazy background.

(10) In high myopia vitreous opacities are sometimes numerous and most annoying.

(11) Myopes often stoop very much and become

"round-shouldered" from their habit of poring over their work, and this stooping at near work tends to produce congestion of the eyes and appendages.

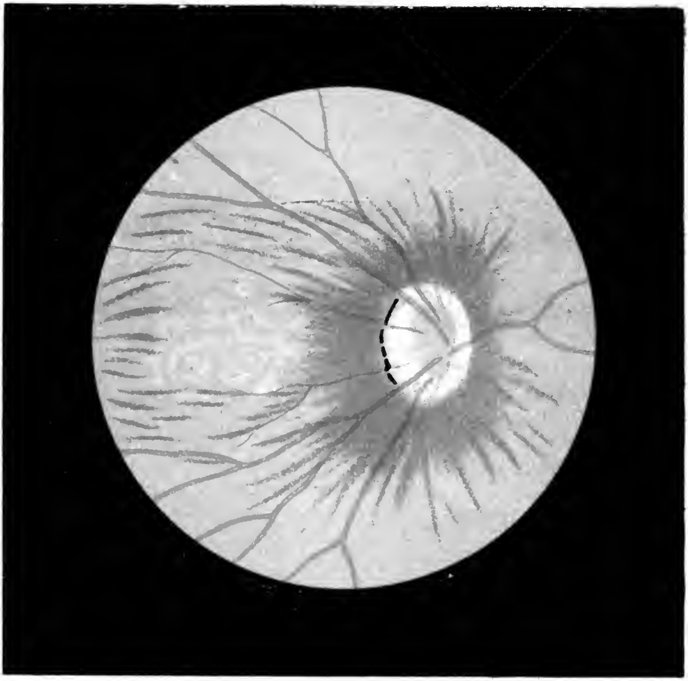
It should be noted that, in low degrees of myopia, often the only symptom present is indistinct distant vision, and this, very often, is not recognized by the patient as a defect. Such people learn to recognize indistinct outlines by the aid of other senses in a way that emmetropes can hardly understand, and when, in later life, they can put off the wearing of glasses for near work for many years, or till extreme old age, what wonder that they and their relations imagine them to be possessors of remarkably good sight!

The Diagnosis of Myopia by Examination.

Objective Examination—*The Ophthalmoscope:* (1) *The Indirect Method.*—By this method the disc appears smaller than in emmetropia. On withdrawing the focus-glass from the patient's eye the disc becomes larger. Without the focus-glass, in high myopia the fundus is seen very large and inverted, if the observer be not nearer the aerial image than his own near point, and if the observer's head be moved, the image of the disc appears to move in an opposite direction.

(2) *The Direct Method.*—By this method—viz., with the ophthalmoscope close to the eye—the fundus is indistinct, and the concave glasses have to be rotated in front of the opening; the weakest concave glass that gives a distinct image is the measure of the myopia, if the observer's accommodation is relaxed.

Retinoscopy.—With a plane mirror the shadow moves "against," and with a concave mirror "with," if the observer be beyond the patient's far point. With the observer seated 1 metre from the patient, the measure of myopia is that concave lens which gives the point of reversal, with -1 D added (see page 79).



THE FUNDUS OF THE RIGHT EYE OF A MYOPE.

The amount of myopia is 9 D, and correction gives normal vision.

The retinal vessels are very straight, and they are seen to curl over the tilted nasal margin of the disc.

The "myopic crescent," instead of being limited to the outer or temporal side of the disc, is seen to surround it.

[The fellow eye is much the same, only the changes at the macula are more marked, and vision is only $\frac{6}{12}$].

Subjective Examination.—Having ascertained the amount of error by the above methods, we seat the patient before the test types, and proceed to correct with concave lenses in the trial frame.

As the accommodation is never so relaxed as when the eye is under the influence of a cycloplegic, the patient may require a slightly stronger lens than the objective examination indicated. Thus, if retinoscopy at a metre from the patient gives us the point of reversal with -5, we call the amount of defect -6, and before the types the patient may prefer $-6{\cdot}5$.

Note the *weakest* lens that gives the most distinct vision with each eye separately, and then try the glasses binocularly when binocular vision exists, as sometimes the patient will accept and prefer a slightly weaker glass.

As the circles of diffusion are removed by correction, the myope often finds that concave glasses reduce the size of objects. In Fig. 21, page 26, M represents the position of the myopic retina, and the image of an object on it is seen to cover a larger area than the same object does either in emmetropia or hyperopia, H.

Changes in the Fundus in Myopia.—In most myopes a white crescent is observable on the temporal side of the disc; this is the myopic crescent. It may not be limited to this part, and may even surround the disc (see frontispiece). In high myopia it often extends on the outer side towards the macula. Its margins are often pigmented. This crescent, which is a localized atrophy of the choroid, is brought about by the stretching of the tunics in the formation of the posterior bulging or staphyloma posticum of the eyeball. The "dragged disc" is due to the resistance of the optic nerve (often shorter than normal) on the one side, and the posterior staphyloma on the other. Whether the atrophy is secondary to choroiditis or merely due to insufficient nutrition, it is difficult to say. Von Graefe asserted that the staphyloma posticum is due to a sclerotico-choroiditis. If this be so, then this particular spot bulges, because it is unsupported by the recti which compress the sides of the globe. This also explains why undue convergence, by increasing the intraocular pressure by pressing the recti on the globe, is such an important factor in causing and increasing myopia. The dragged or tilted disc is very characteristic, and becomes deeply cupped in some cases. This cupping is quite distinct from glaucomatous

cupping, in that it is most marked on the nasal side, the vessels rising up and dipping down over the tilted edge in a very characteristic fashion, and it does not occupy the whole area of the disc (see frontispiece).

If the myopia progress, the changes may become general, and after a time white patches of choroidal atrophy, with masses of black pigment forming their boundary, are scattered all over the fundus. These changes extend to the vitreous, causing liquefaction of that body and the subsequent shrinking, and the consequent loss of support to the retina may end in detachment of that membrane. Unfortunately, very often some of the most serious changes occur at the macula, as this is the region of the bulging, and hæmorrhages and consequent atrophy lead to a result as disastrous as the detachment.

Some cases of high myopia have been termed "malignant," and it is very probable that many of them ought not to be classed under myopia at all, but that the myopia is only a symptom of a disease attacking the eye.

The milder cases of progressive or malignant myopia (wrongly so called) are often the result of wrong treatment, as we shall see.

Treatment—

Donders said: "The effect of wearing glasses is, in fact, that the relative range of accommodation is displaced, becoming gradually the same as the position proper to emmetropic eyes, and therefore the binocular furthest point approaches the eye while the absolute furthest point *r* by no means does so. The myopia thus neutralized is less progressive, because both too strong convergence and a stooping position are avoided."

Since his day some ophthalmologists have advocated the practice of allowing those suffering from low myopia to do near work without glasses, and when the myopia was high, have given weaker glasses for near work. The consequence has been that as the convergence was still being used in excess, the myopia tended to progress. If Donders' teaching had been followed, this error would never have been made, an error which has kept progressive myopia and malignant myopia dreaded for so many years.

Following on Donders' teaching, and making use of our increased knowledge, which indicates the importance of correcting low errors of astigmatism, we

have made great advances in recent years. The full correction of the error (with the smallest minus cylinder), except in cases of very high myopia, leads not only to the arrest of the progress of the myopia, but in some cases to its distinct diminution.

In a paper read in 1904 at the British Medical Association meeting at Oxford, I cited 532 myopes who had been treated by *full correction*.

The myopia ranged from ·75 to 20, and the average period of observation was four and a half years. The following table shows the result:

532	469 remained stationary, and of these, in 162, the visual acuity improved.	
	63 progressed.	Increase limited to 1 D, 47.
	Average age, 15.	,, ,, 2 D, 13.
	M. from −1 to −11.	,, ,, 4 D, 3.

If we exclude the 27 whose increase was limited to 1 D, we have 16 left—*i.e.*, only 3 per cent. progressing.

In early life the treatment of myopia is mostly preventive. It is rare to come across a child under the age of 6 with actual myopia. Apparent myopia may show itself—(*a*) from spasm of the ciliary muscle, distant vision being subnormal and improved by concave glasses, and near work being approached very close to the eyes; (*b*) in a young patient with high hyperopia, in which case distant vision is poor, and near work is held very near to the eyes in order to acquire large retinal images; (*c*) in children who have acquired the habit of holding their work near the eyes, either through faulty illumination or on account of reduced visual acuity, produced by some disease of the eyes, such as corneal nebulæ.

In all these cases the true error is revealed by a cycloplegic, consequently no attempt should ever be made to treat a young myope without previously paralyzing the accommodation, and *atropine* should, if possible, always be used.

The preventive treatment is more especially indicated in all children whose parents are myopic, for they have

probably inherited an "anatomical predisposition" to myopia.

Bearing in mind that excessive convergence is the most potent cause of myopia, the most rigid attention should be paid to ophthalmic hygiene. The schoolroom should be lofty and large, and have high windows on one wall. The seats and desks should be arranged in rows so that the students sit with the windows on their left. When practicable, each scholar should have an adjustable seat and desk, but when this cannot be arranged, as most children of the same age are of the same height while sitting, and in the same class, the height of the desk from the seat should increase gradually with the classes, the highest class having the highest desks.*

The school work that needs close application of the eyes should be continued only for a short period at a time, the period alternating with other work which does not require the use of the eyes, such as mental arithmetic, demonstrations, or play.

Schoolmasters should teach more—that is, they should explain and impart knowledge by demonstrations and simple lectures, and reduce as much as possible the time spent in "home preparation," which is usually work done by bad light, and when the student is physically and mentally tired.

Even in the nursery the greatest care should be taken with the children's sight. They should have large toys, and among these there should always be a large box of plain wooden bricks; picture-books should be discouraged, and close work that entails undue convergence, such as sewing, threading beads, etc., should be forbidden. The nursery governess can teach them their letters and small words, and even simple arithmetic, by means of the wooden bricks.

* The desk should have a slight slope, and its height should be so regulated that the scholar can sit with head upright and the eyes about 33 cms. from the work.

No child with a tendency to myopia or with a myopic family history should be allowed to learn to write or to draw until at least 7 years old.

The child's bed should not be allowed to face the window; preferably it should be back to the light.

Having ascertained the concave glass that corrects the myopia of each eye under atropine, we may, in quite young patients, order such glasses for constant use; in those over puberty it is wise to delay prescribing until the effects of the atropine have passed off—not only because an increase of ·5 may very distinctly improve vision, but because it is important to try the glasses binocularly when the eye is in the normal state. It is too often forgotten that the eyes are not single optical instruments, and we often find that a *weaker* pair of concave glasses give as good vision as a stronger glass used monocularly.

The only certain method of arresting the progress of myopia is to establish a normal state, in which the ciliary muscle is strengthened by being forced to work, the excess of convergence over accommodation stopped, and excessive convergence made impossible, and this can only be achieved by insisting upon the *constant* use of the glasses, and *refusing to give weaker ones for near work.* The patient can see his near work so much better *without glasses* that we may have some trouble at first in enforcing this treatment.

Of course, the precaution must be taken of removing the glasses when rough games are being played.

In adults the treatment of myopia should be carried out in the same manner, substituting homatropine for atropine in those who cannot afford the time from work that the latter entails.

If the myopia be somewhat high, say 6 D or over, and has never been fully corrected, we may have to give glasses for near work 1·5 or 2 D weaker, but the patient

should be strongly advised only to wear these on special occasions when fine work is being done, or by artificial light.

The older the patient and the higher the myopia the more difficult will it be for him to use the distance glasses for near work, because his accommodation has been so long idle that the ciliary muscle is considerably atrophied.

If the patient be a student or engaged in literary or other work which entails close application for many hours a day, and if he be free to regulate his work, he should be advised to work for shorter periods and take longer intervals of rest, and be especially careful to have his work always in a good light.

In patients of 30 years of age and up to 40, homatropine should be used when practicable. Over 40 no cycloplegic is required. If the patient has never had the full correction, he will at this age be unable to read with his distance glasses, and weaker ones must be given, preferably in the form of bi-focals. All the more will this be the case when he arrives at 40 or 45, the emmetrope's presbyopic period; no rigid rule should be observed, but each case should be treated according to its requirements.

After carefully testing the patient, we should find his working near point, and keep more accommodation in reserve than would be required in the emmetrope because the ciliary muscle is weaker (see Presbyopia, page 150).

Some adults with a small amount of myopia obstinately refuse to wear the constant correction: ladies will wear lorgnettes at the theatre, etc.; men will wear a monocle. If no astigmatism be present, this may be allowed, so long as no increase in the myopia takes place, but only on the condition that the patient is re-examined at frequent intervals.

High Myopia.—The treatment of high myopia is somewhat different. When the young adult has never worn the full correction, it will be useless to prescribe it, even

for distance, at first. We should reduce the glass as little as possible, and test binocularly. For instance, the myopia may be 20 in both eyes, but − 18 before each eye is the strongest glass the patient will tolerate. These we order for constant use, and we may find that later the full correction will be accepted. In older patients, not only have we to be satisfied with a reduction in the distance glasses, but we must often take off as much as 4 D for near work.

Adults who have, say, 10 D of myopia, will very often refuse to wear this correction because of the discomfort entailed; in such cases it will be found that the best method is to give, say, 8 D for constant use, and to give them 2 D either as lorgnettes or as a "spy" glass to put up in front of the 8 D when they want particularly to see at a distance.

The advantage of this treatment is that the "constant" glass, being weaker, may do quite well for reading.

When recent fundus changes are present in young patients, the eyes should be kept under atropine for a long period, the correcting glasses should be well tinted, or made with Crookes's "B" glass (see below), and a country, open-air life should be strongly recommended, with complete cessation of all close work while the changes are active; older patients should be warned against stooping or straining, and should be strongly advised to do little, if any, near work. In all these cases so much depends on the general health that it is wise for the surgeon to place them under the care of a physician, who, among other things, can advise as to aperients, the means of reducing high blood-pressure when present, etc., and by this care we may avert retinal hæmorrhage which is so liable to occur.

When any fear exists as to the possibility of detachment of the retina ensuing, the patient should be especially warned against riding on horseback, jumping, or doing any act which may jar the body.

The Treatment of High Myopia by Discission and Removal of the Lens.—When the patient is not older than 25, the myopia very high, vision very poor, and not improved by glasses beyond $\frac{6}{24}$, and when the fundus changes are not very marked, and especially when the myopia is progressive, the lens may be removed by discission. The improvement is sometimes very great, the patient being able to see better without a glass than he did previously with a strong concave lens. (For details of this treatment the reader should consult a textbook on ophthalmology.)

Crookes's Glass (see page 211).—It is advisable to have the correction of myopes made with Crookes's "A" glass. In high myopia this special glass is imperative, and where the myopia is progressive Crookes's "B" should be used.

CHAPTER VIII

ASTIGMATISM

In discussing errors of refraction, it has been shown that both hyperopia and myopia are mainly due to an alteration in the shape of the eye as a whole, the antero-posterior axis being too short or too long—axial ametropia; but the fact was also mentioned that alterations in the curvature of the cornea or lens would produce these errors, that if the curvature were too flat,

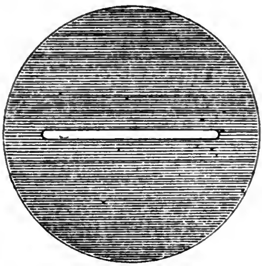


Fig. 58.

parallel rays would focus beyond the retina, and if too great, in front of the retina. It is these errors of curvature that will now be considered.

In the normal standard eye, if an opaque disc with a slit aperture (Fig. 58) be placed in front of it, at whatever angle this slit is rotated, distant objects will be seen through it distinctly—that is, parallel rays will focus on the retina. In simple hyperopia and myopia the same

result is obtained after correcting the ametropia with a spherical lens, because the surfaces of the dioptric apparatus are perfect spheres, and consequently all the meridians have the same curvature. But suppose we examine an eye in which the vertical meridian is normal —*i.e.*, parallel rays, passing through this meridian, focus on the retina—but in which the horizontal meridian has a flatter curvature, then parallel rays passing through this flatter curvature will focus beyond the retina, and as they impinge on the retina will form diffusion circles. In such a case all the meridians, between the horizontal and

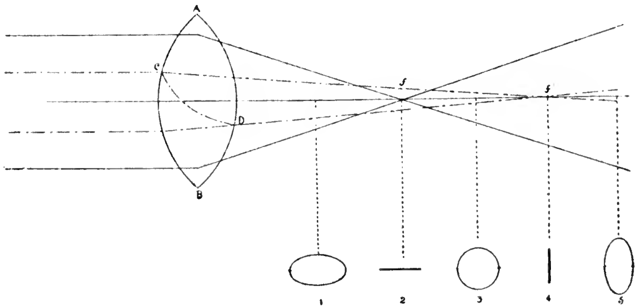


FIG. 59.*

vertical, will have a different focus point, such points gradually approaching the retina as the meridian becomes more vertical.

Such an eye is astigmatic, and **astigmatism may be defined as an ametropia of curvature,** a condition in which rays of light, passing through the dioptric apparatus, do not all focus at one point.

In *regular* astigmatism, of which the above is an example, and which is now under discussion, the meridians of greatest and least curvature are always at right angles to each other, and are called the principal

* For the sake of simplicity, the two principal meridians only are shown.

meridians; the meridians in between these have a greater or less curvature, according as they are nearer to the former or to the latter. The meridian exactly between the two (corresponding to an angle of 45° if the meridians of greatest and least curvature are vertical and horizontal) has its focus point exactly between that of the greatest and that of the least curvature.

The bowl of a spoon is an exaggerated example of an astigmatic surface, the curve from side to side being much greater than that from the handle to the tip of the spoon.

Fig. 59 shows in a highly diagrammatic manner the shape of the images formed by a regular astigmatic surface. Let the vertical meridian have a curvature A B, so that parallel rays passing through it focus at *f*. Let the horizontal meridian C D have a flatter curvature, so that rays passing through it focus beyond *f* at *f′*.

If a beam of light pass through such a surface, and the resulting cone of light be intercepted at the different positions 1 to 5, the image will be altered in shape according to its position.

At *f* the vertical rays have come to a focus, and therefore form a point of light; but the horizontal rays have not come to a focus, and will be spread out, as at (2), into a horizontal line, called the anterior linear focus. The reverse obtains at *f′*, as shown at 4, because the horizontal rays have come to a focus, and the vertical have crossed and form diffusion circles and spread out the points of light into a vertical line, called the "posterior linear focus." At 1 none of the rays have focused, but the vertical are nearer the focus than the horizontal, so the figure here will be an oblate ellipse. At 3 the vertical rays, having crossed, are diverg ng as much as the horizontal are converging, and here the figure is a circle. At 5 the vertical rays are more out of focus than the horizontal, so that the figure is a prolate ellipse.

When the retina is situated at any of these positions (1 to 5), the image on the retina will be something like the diagrammatic sketch. The interval between f and f'—*i.e.*, between the focal points of the principal meridians—is called the "focal interval of Sturm," and represents the amount of astigmatism.

The vision of an astigmatic person, when the astigmatism is sufficiently high to cause a defect of vision, is different from that of the defective vision of the hyperope or myope. Objects may not appear blurred generally, but only in parts; lines are lengthened or broadened, and circles appear elliptical. He may be able to read some letter in $\frac{6}{6}$, but even in line $\frac{6}{18}$ he may not read all correctly; he supplies the visual deficiency by guessing.

FIG. 60.

In every eye affected with regular astigmatism there is one direction in which straight lines appear most distinct, and another at right angles to it in which the line is most indistinct; hence, if two lines at right angles to each other are held before an astigmatic eye, they cannot both be distinct: if one is in focus, the other is blurred.

In Fig. 59, where the vertical meridian is more sharply curved than the horizontal, at the anterior linear focus (f) a horizontal line will appear in focus, but a vertical line blurred; and at the post-linear focus (f') a vertical line will appear in focus and a horizontal line blurred; they cannot both be in focus at the same time.

Thus, when two lines at right angles to each other (A and B, Fig. 60, *a*) are looked at by an eye affected with simple astigmatism, if the *vertical* meridian be defective, A will appear defined and B blurred, because A is spread out vertically and this does not affect the definition, while the vertical "spreading out" of B makes the line appear blurred (Fig. 60, *b*). If the horizontal meridian be defective, the reverse happens (Fig. 60, *c*).

Varieties of Regular Astigmatism (Fig. 61):

Variety of Astigmatism.	Refraction of the Principal Meridians.	Position of the Principal Focus.
1. HYPEROPIC ASTIGMATISM—		
(*a*) Simple.	Emmetropic. Hyperopic.	On the retina. Behind the retina.
(*b*) Compound.	Both hyperopic.	Both behind the retina, one being nearer than the other.
2. MYOPIC ASTIGMATISM—		
(*a*) Simple.	Emmetropic. Myopic.	On the retina. In front of the retina.
(*b*) Compound.	Both myopic.	Both in front of the retina, one nearer than the other.
3. MIXED ASTIGMATISM.	Hyperopic. Myopic.	Behind the retina. In front of the retina.

Generally, the vertical meridian, or one near it, is most convex, and this is called "direct astigmatism." Thus, in direct astigmatism the horizontal meridian (or one near it) is hyperopic in simple and mixed astigmatism and most hyperopic in compound hyperopic astigmatism, and the vertical meridian (or the one near it) is myopic in simple and mixed astigmatism and most myopic in compound myopic astigmatism. In Fig. 61 all the examples show direct astigmatism. If the conditions are reversed, it is called "inverse astigmatism."* When the meridians are exactly oblique—*i.e.*, at an ang e of 45° or 135°—it is called "oblique astigmatism."

Symmetric Astigmatism is when the axis of the principal

* The old nomenclature of these two forms was "astigmatism according to (or with) the rule" and "against the rule."

meridian in each eye is identical; for instance, the meridian of greatest curvature is vertical in both eyes, or is 15° from the vertical passing down and in, in both eyes; and *Asymmetric Astigmatism* is the reverse.

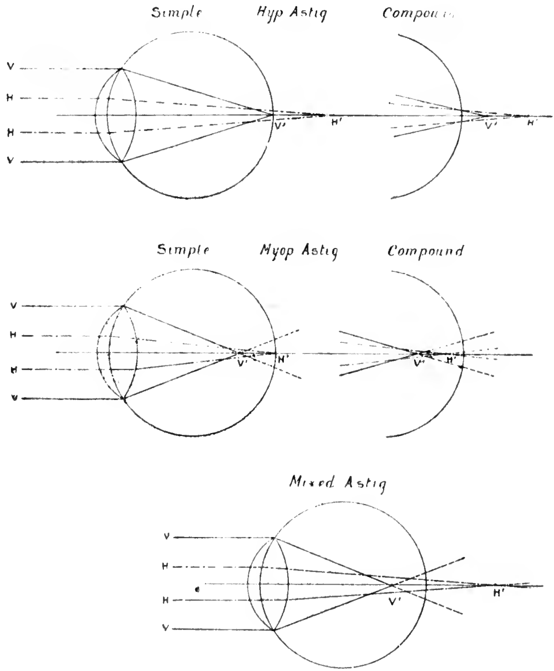


FIG. 61.

V, Rays passing through the vertical meridian; H, rays passing through the horizontal meridian.

Homonymous Astigmatism is when the axes of the principal meridians in each eye are more or less parallel; for instance, the axis of the correcting cylinder passes down and *in* 15° from the vertical in the right eye and 10°, 15°, or 20° down and *out* in the left eye.

The Seat of Astigmatism.—In regular astigmatism the seat is chiefly in the cornea, due (1) to congenital malformation of the cornea, often traced to heredity; or (2) to acquired alteration in the curves of the cornea, produced by operations, such as iridectomy and operations for cataract, or inflammation of the cornea; or (3) to pressure from tumours in the lid.

Transient astigmatism can be produced by pressure on the eye with the finger, or by contraction of the lids or the extra-ocular muscles. Congenital corneal astigmatism is, more or less, stationary through life; acquired astigmatism of the cornea alters, and very often is considerably reduced by time.

Even in the normal eye there is a certain amount of astigmatism, but this "physiological" astigmatism is so small that it can, in most cases, be ignored.

The *lens* may also be the seat of astigmatism, which may be "static" or "dynamic."

The static lenticular astigmatism is generally small in amount, and, being in the same meridian, adds itself to that of the cornea, thus increasing the total astigmatism of the eye; but sometimes this lenticular astigmatism is the reverse of that of the cornea, and so corrects it.

Dynamic Lenticular Astigmatism is nearly always corrective, and is the opposite of that of the cornea. It is produced by an unequal contraction of the ciliary muscle, and is a most potent factor in causing eyestrain.

Symptoms of Astigmatism.—When the astigmatism is *pronounced*, acuteness of vision is below the normal. Spherical glasses may improve the distant sight to a certain extent, but the correction is never complete. On directing the patient to look with one eye at the "Fan" (Fig. 62), placed 5 or 6 metres off, or nearer if necessary, we find that he can see certain lines more distinctly than others. The vertical lines may be seen quite black and distinct, the horizontal lines being faint, or *vice versa*; or the oblique lines on one side may be distinct, those on

the other side, at right angles to the former, being indistinct. If all the radiating lines are indistinct, we must make one of the meridians emmetropic, by placing before the eye the weakest concave or strongest convex spherical glass that is required to make one set of lines distinct and black.

As we have already seen, when rays coming from a point are refracted at an astigmatic surface, a linear image of the point is formed at the focus of each principal meridian, and the direction of the linear image *is at right angles* to the meridian at whose focus it is formed. Thus, when a patient sees the horizontal lines distinctly and the

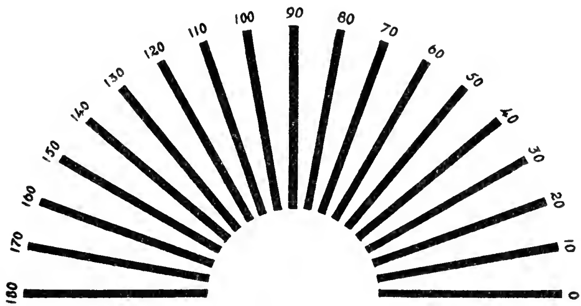


Fig. 62.

lines as they pass to the vertical become less distinct, reaching the maximum of indistinctness in the vertical lines, we know that the *vertical meridian* is emmetropic, or nearly so. Such a patient would complain that the letters of the test type were spread out horizontally, and if we place before the eye a stenopaic disc with the slit vertical, we shall find the phenomena of astigmatism disappear; he sees all the lines with equal clearness, and the letters appear normal, because the vertical slit has cut off all the horizontal rays that caused the blurring.

Astigmatic Headache.—Eyestrain is the commonest symptom of astigmatism, and of all the forms of eye-

strain, headache is by a long way the commonest. The strain is produced in two ways:

1. When the astigmatism is *pronounced,* the eye has to accommodate in order to obtain clearer images.

Sturm asserted that accommodation was not made for either of the linear foci, but for a point between the two where the image is approximately a circle; but Javal, in his later researches, found that it was the vertical focal line that was sought after.

Tscherning points out that among the reasons for this preference is the fact that in reading, the legibility of the letters depends especially on the distinctness with which the *vertical* lines are seen. We can prove this for ourselves by holding up before one eye (the other being closed) a concave cylinder of, say, 1·5 D, with its axis vertical; if we turn the axis round to the horizontal, making ourselves vertically hyperopic, the letters are spread out vertically, and the words are very much clearer.

2. *Meridional Asymmetrical Accommodation.*—When the astigmatism is small, the error can be corrected by an unequal contraction of the ciliary muscle, producing an astigmatism of the lens the opposite of that of the cornea.

With few exceptions, the seat of regular astigmatism is in the cornea, due to a difference in the curvature of the different meridians; added to this there is sometimes found a "static lenticular astigmatism," due to a difference in the curvature of the different meridians of the lens, and the two together make up the total astigmatism of the eye which is revealed under an ordinary examination. But most frequently, although astigmatism of the eye is suspected, where it is of low degree it may be impossible to detect it without resorting to a cycloplegic. Donders in 1864 first drew attention to this, and he pointed out that the corneal astigmatism, when small in amount, was corrected by an *astigmatism of the lens;* thus, if there was direct astigmatism of the cornea of ·25,

there would be inverse astigmatism of the lens of the same amount, neutralizing and masking the defect. Dobrowolsky in 1868 asserted that this lenticular astigmatism was produced by an *unequal contraction of the ciliary muscle;* and Hensen and Voelckers, later, have shown by experiments upon animals that this unequal contraction is possible. They showed that when a filament of the ciliary nerve was divided, the portion of the muscle supplied by it was relaxed, and that on stimulating the cut end a local contraction took place.

But, in addition to this physiological proof, the clinical proofs are even more conclusive.

Let us take a typical case. A patient complains of headache, accentuated by near work. Examination reveals no refractive error. The ciliary muscle is paralyzed, and astigmatism is discovered. This is corrected by cylinders, the glasses are ordered to be worn always, and in a short time the headache disappears.

Again, very often when the effect of the cycloplegic has passed off, the patient refuses the cylinder that improved his vision under atropine. He tells you that it makes his vision worse. In spite of this you prescribe it, and—this is a very important point—you insist on the glasses being worn always. He returns in a month or two, assuring you that his headache has entirely disappeared, that he has become accustomed to the glasses, but that he cannot now see as well without them as he could before using them.

What has happened? At first, when the effect of the atropine has passed off, the ciliary muscle returns to its old habit of unequal contraction, and consequently the correcting glasses, instead of helping, make matters worse; but by constantly wearing them the necessity for this unequal contraction disappears, the muscle resumes the normal condition, and allows the glasses to do the work. Vision is apparently worse without the glasses, because the muscle has forgotten its bad habit; but, of

course, like all bad habits, it can be easily re-acquired. The patient has lost nothing but his headache. What stronger proofs could there be that this unequal contraction does occur?

Further, as lenticular astigmatism must necessarily be very small, probably rarely higher than ·5, it can only neutralize a low degree of astigmatism in the cornea, and it is in these cases where headache is most frequent.

It is easy to understand how this unequal contraction of the ciliary muscle causes discomfort or pain, especially in a neurotic subject. It may be also that several causes are present, such as constipation, worry, etc., and that this form of eyestrain is the "last straw on the camel's back." Sometimes it is only towards middle age, when the accommodative power is lessened, or the nerve energy lowered, that the strain shows itself.

This unequal contraction of the ciliary muscle must interfere with the nutrition of the lens, and it is most likely a very potent factor in the causation of cataract.

In high astigmatism there may be some asymmetry of the face, but otherwise there are no physical appearances that indicate astigmatism. In oblique astigmatism the patient may acquire the habit of holding the head on one side, but this is not always the case; on the other hand, if a patient, in reading the distant types, does hold the head obliquely, we may be almost certain that oblique astigmatism is present.

Diagnosis and Measurement of Astigmatism.—There are numerous methods for detecting and measuring astigmatism, and they may be ranged under two heads:

1. Objective Methods—

(*a*) *The Shadow Test, or Retinoscopy* (see page 74).—The patient being, if possible, under the influence of a cycloplegic, the refraction of the different meridians is estimated in the manner described on page 78. When all the meridians have the same refraction, there is no astigmatism; when there is a difference, astigmatism is

present, and its degreee is estimated by the difference between the meridian of least and the meridian of greatest refraction. The axis of the correcting cylinder will be in the same direction as that of the meridian of least refraction (see Shadow-test, page 78). For instance, supposing we find the vertical meridian shows a hyperopia of 1·5 and the horizontal a hyperopia of 2·5, then the astigmatism equals 1, and the axis of the convex cylinder is vertical. Or, again, using a concave mirror, supposing we find the shadow moves "against" in the direction 15° from the vertical down and in and a +2 corrects, and the meridian at right angles gives a shadow "with" corrected by −1, we have mixed astigmatism amounting to 3 D and corrected by a concave cylinder −3 placed 15° from the vertical down and in and a +1 sphere, or a convex cylinder +3 with its axis 15° from horizontal down and out and a −2 sphere.

Retinoscopy is a very valuable help in estimating astigmatism; it is accurate and simple, but is not so delicate as the ophthalmometer.

(*b*) *The Ophthalmometer.*—The instrument first suggested by Helmholtz, and improved by Javal and Schiotz, has been made in many forms, but perhaps the model made by Meyrowitz is the best (Figs. 63 and 64).

The ophthalmometer measures the curvatures of the cornea, and thus enables us to ascertain the presence of astigmatism, and, if present, its amount, the direction of the principal meridians, and the character—*i.e.*, whether we are dealing with direct, inverse, or oblique astigmatism—and all this information is acquired in a very short space of time by the expert. Moreover, the patient is passive, the examination being purely objective, and, as such, of immense value in checking the subsequent subjective test.

It is true that the ophthalmometer only gives information concerning the astigmatism of the *cornea*, and not the total astigmatism of the eye, but this is exactly the information we want; for, as we have seen (page 121), the lenticular astigmatism when *dynamic* is a corrective astigmatism, and disappears under a cycloplegic. It naturally follows that, useful as this instrument is in every case, in those cases where for some reason a cycloplegic is prohibited, the ophthalmometer is *exceptionally* valuable, and in the diagnosis and estimation of low errors of astigmatism it is *indispensable.*

The essential parts of the instrument are two mires, whose images are reflected on the cornea of the patient, and which are seen by the observer through a telescope containing a double prism between two bi-convex lenses. The patient's chin rests on a support, and his forehead should press against the top of the stand to insure perfect rest, and the eye not being examined is covered by a sliding clip. The mires are carried on an arc which can be rotated into any position, and there is a graduated

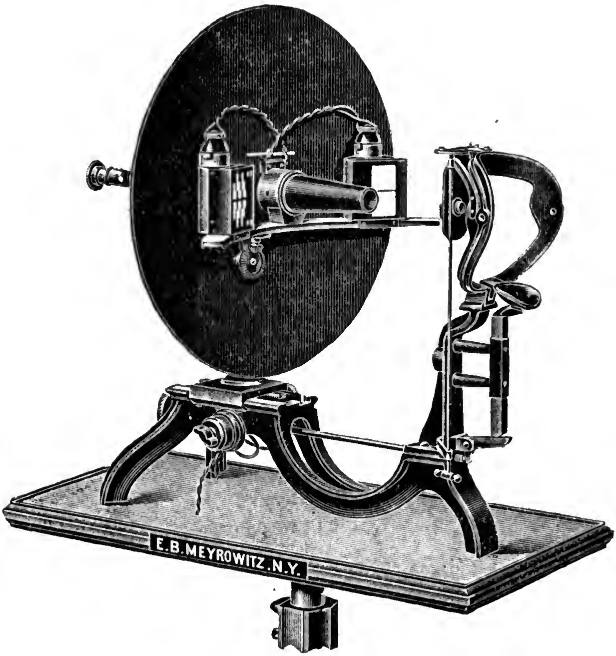


FIG. 63.

disc on the observer's side of the instrument, which, by means of a pointer, shows the meridian of the arc (Fig. 64).

The two mires are made of porcelain, and illuminated by electric lamps behind them; they are operated by means of a gear movement, and are thus made to approach or separate from each other, their position being indicated by pointers working on a disc on the observer's side (Fig. 64).

When electricity is not available, gas or lamps must be used at

the side of the patient's head and reflected on to the mires, as ordinary daylight is an insufficient illuminant.

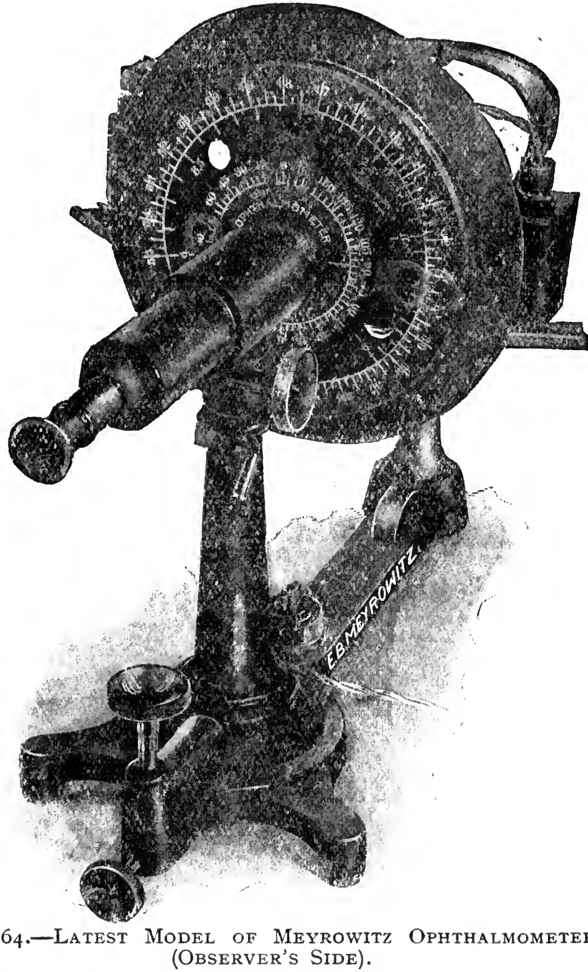


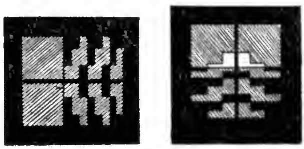
FIG. 64.—LATEST MODEL OF MEYROWITZ OPHTHALMOMETER (OBSERVER'S SIDE).

Seated on the other side of the stand, the surgeon looks through the eyepiece and points the telescope to the eye, and, by means of

a rack and pinion on the upright, moves it up or down until he sees four figures on the patient's cornea, which are two reflections of each of the mires.* Ignoring the outside figures, he now accurately focuses the two inside ones by means of a rack and pinion.

The first step is to ascertain the axis of the astigmatism when present, and we start with the arc horizontal, and note whether, in the reflection of the two mires, the deep black line which runs through the centre is a continuous black line running through both; if not, the arc must be revolved to the right or left (but never more than 45°) until this result is obtained; we then read off the axis on the dial. The next step is to so adjust the mires that their reflections are just in contact, as in Fig. 65, *a*. This, then, is the primary position of the ophthalmometer—viz., with the central black lines of the two mires forming an unbroken black line, and the two inner edges of the mires just in contact.

We now revolve the arc through a complete right angle, and if the relative position of the reflected mires has not changed, then there is no corneal astigmatism; but if, with the arc vertical



a *b*

FIG. 65.

or nearly so, the reflections overlap (as in Fig. 65, *b*), there is direct astigmatism, each step of the reflected mire overlapping representing one dioptre of astigmatism; or, to be more correct, we note the exact position of the underneath pointer on the disc, bring the superficial pointer exactly over it, then readjust the mires so that they are again *in contact*. If astigmatism is present, the two pointers are separated by an interval which represents the amount of the astigmatism, which amount is indicated by the divisions on the disc.

If, on revolving the arc from the horizontal to the vertical position, the reflections separate, we are dealing with inverse astigmatism, and we must then make the secondary position our primary position, and proceed as before.

If used as a servant, and not allowed to become master, the ophthalmometer is one of the most valuable adjuncts to the ophthalmologist's consulting-room, for after some practice, and

* The telescope has an adjustable eyepiece at the surgeon's end, and in the centre an achromatic objective, which has between its two bi-convex lenses a bi-refringent prism.

when thoroughly mastered, in about one minute the observer ascertains (1) whether astigmatism is present, (2) the amount, and (3) the direction of the axis of the principal meridian; and, moreover, this is done with such delicacy that one-eighth of a dioptre of astigmatism is revealed. It is also the quickest method of diagnosing irregular astigmatism (see page 139).

In low errors, probably owing to some static astigmatism of the lens, the total astigmatism of the eye generally shows about ·25 of inverse astigmatism, in addition to the ophthalmometric measurement. Thus, when the ophthalmometer shows *no* astigmatism, there is ·25 inverse astigmatism; when it shows direct astigmatism, there is ·25 less; and when it shows inverse astigmatism, there is generally about ·25 more, but this varies in different instruments; the particular idiosyncrasy of any instrument is very soon discovered.

The following points should be very carefully observed, in order to prevent inaccurate results:

1. Impress upon the patient the imperative necessity of keeping the forehead pressed against the stand. If on turning the arc into the secondary position the mires have to be refocused, we know the patient has moved. Once the mires are focused in the primary position, the focusing must not be altered.

2. It is equally important to insist upon the patient looking all the time into the centre of the telescope; otherwise an astigmatism will appear which is not a *central* astigmatism, and is consequently not the astigmatism we wish to ascertain.

Hardy's ophthalmometer, in which the mires are stationary and the prisms are movable, is said to be a more accurate instrument, but I have personally failed to confirm this.

The Sutcliffe keratometer, which is a one-position ophthalmometer, is said to be a very reliable instrument. A full description will be found in the *Ophthalmoscope*, April, 1909.

(*c*) *The Ophthalmoscope.*—Ophthalmoscopically, astigmatism is revealed by observing that all parts of the fundus are not in focus at the same time, no matter what lens we turn into position.

Estimation of the Amount of Astigmatism by the Ophthalmoscope.—Bearing in mind the fact that vertical vessels are seen through the horizontal meridian, and horizontal vessels through the vertical meridian, we focus, for instance, the vessels passing horizontally from the disc to the macula, and find the weakest concave or

strongest convex glass that gives us the best picture; this will, of course, give us the refraction of the meridian at right angles to this—viz., the vertical. We then focus the vessels that pass up or down from the disc, and estimate thus the refraction of the horizontal meridian, and the difference between the two meridians is the measure of astigmatism.

When the principal meridians are not horizontal and vertical, we focus vessels passing obliquely—say up and out from the disc—and afterwards those passing down and out, and so on.

The patient must be under a cycloplegic, and the observer's accommodation must be relaxed, which introduces the personal element and causes this method to be rarely used by ophthalmologists in preference to retinoscopy or the ophthalmometer.

It is important to remember that the vessels to be observed should be those situated near the macula, because we are estimating the refraction of the central part of the dioptric system.

It is hardly necessary to add that this method is not delicate enough for the diagnosis of small errors of astigmatism.

The Ophthalmoscope by the Indirect Method.—This is of little use in diagnosing low errors. When the error is pronounced, the optic disc appears oval, and its elongation is in the meridian of least curvature. When the focus-glass is withdrawn from the eye, if the aerial image remain the same size in one meridian but become smaller in the other, the case is one of simple hyperopic astigmatism; and if the image become larger, it is a case of simple myopic astigmatism. In compound hyperopic astigmatism the image becomes smaller in both meridians, but more so in one; and the reverse, of course, in compound myopic astigmatism. In mixed astigmatism, on withdrawing the focus-glass, the disc appears to become relatively larger in the direction of

the maximum, and relatively smaller in the direction of the minimum meridian.

2. SUBJECTIVE METHODS.—(*a*) Methods based on the fact that when astigmatism is present lines running in

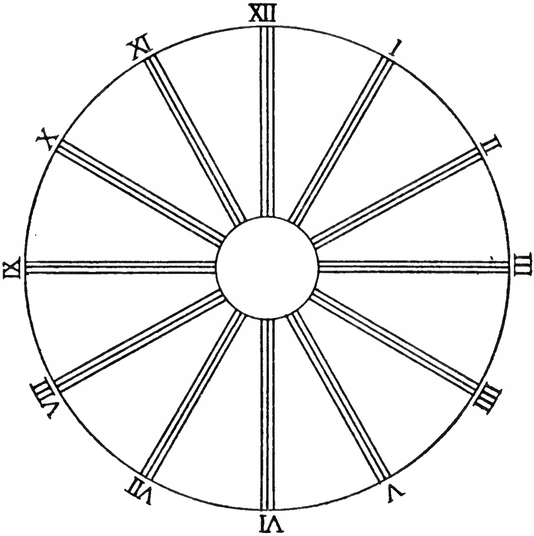


FIG. 66.

different directions are not all clearly seen at the same time—

Clock-face.
The fan, or "rising sun."
"Confusion letters," such as *E* and *Z*.
Pray's letters.

The *clock-face* (Fig. 66) and *fan* (Fig. 62), if observed by a non-astigmatic eye at rest, will be seen to have the lines all equally black; but in astigmatism the vertical lines, for instance, will appear black, while the horizontal are gray, or the oblique down and in, black, and the oblique down and out, gray.

It should be borne in mind that the meridian of the eye which corresponds to the darkest lines is the meridian of greatest ametropia; thus, a patient who requires -1 cyl. axis horizontal to make all the lines appear equally dark has simple myopic direct astigmatism, and sees the vertical lines darkest before correction. The patient's eyes must be under a cycloplegic, and concave or convex spherical glasses may have to be placed in front of the eye to correct any general ametropia present, otherwise the whole chart may be out of focus.

This method is not delicate enough for very low degrees of astigmatism, and, in fact, is rarely used.

Confusion Letters.—There are certain letters which astigmatics often confuse, such as D and O or U, E and Z, S and B, and when a patient on using Snellen's types makes these mistakes we suspect astigmatism.

Pray's Letters are letters printed with stripes running in different directions; the patient selects the letters that appear darker than the others, and the direction of the stripes in the selected letter or letters corresponds to the meridian of greatest ametropia (Fig. 67).

(*b*) **The Chromo-aberration or Cobalt-blue Test,** based on the principle that violet or blue rays, being more refrangible than red, are brought to a focus sooner (Chromatic Aberration).

Cobalt-blue glass contains a great deal of red, and allows only blue and red rays to pass. Such a glass of suitable thickness is mounted in a trial frame placed before the eye to be examined, the other eye being excluded. A clear round point of light should be looked at from a distance of 4 to 6 metres. When the eye is emmetropic, the light appears violet; when hyperopic, the light appears blue in the centre, surrounded by a red ring; and when myopic, red in the centre, surrounded by a blue ring. If astigmatism be present, the light appears oblong, vertically, or horizontally, in different characteristic shapes. Scientifically, this is a most interesting

test, but its weakness consists in the fact that it is purely subjective, and that the surgeon is entirely dependent on the patient's description.

(*c*) **Examination of the Patient before Snellen's Types**—(1) *With the Stenopaic Slit* (Fig. 58).—This is an opaque disc to fit into the trial frame, and through the centre there is a slit about 1 millimetre broad. On looking

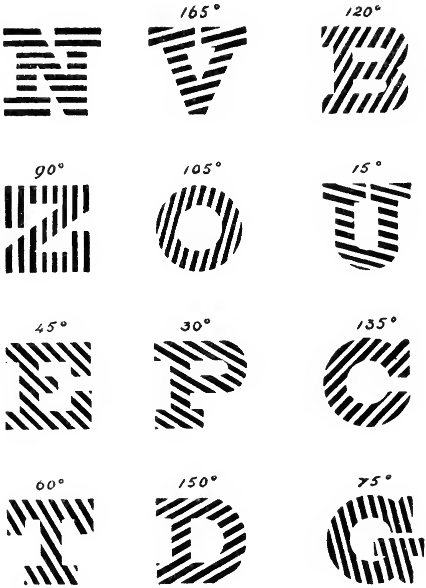


FIG. 67.

through this slit the patient sees only rays passing through the meridian corresponding to the slit; all other rays are excluded, and the glass in front of this slit that gives the best vision represents the refraction of this meridian. The slit is then turned round at right angles, and the refraction of the other meridian is taken. The difference between the two meridians is the amount

of astigmatism, and the value of the cylinder that will have to be employed to correct the defect.

For instance, when, with the slit vertical, $\frac{6}{6}$ is read, and convex glasses make vision worse, this meridian is emmetropic. On turning the slit round, when a +1 glass is required to get $\frac{6}{6}$, this meridian is hyperopic, the astigmatism is 1 D, and is corrected by a cylinder +1 axis vertical.

This method is not very accurate, as much depends on the width of the slit, and better and quicker methods have superseded it; but sometimes in a difficult case of mixed astigmatism it is of assistance.

(2) *With Cylinders.*—This method is too wearisome to be used by itself, but when we have ascertained the refraction by the ophthalmometer and retinoscopy, we always employ it as a final test.

Treatment.—All those engaged in refraction work should observe two golden rules:

First Rule: Always suspect the presence of astigmatism.

Second Rule: Never be satisfied that astigmatism is eliminated unless the examination has been made under a cycloplegic in all under forty or forty-five years of age.

There is no refractive error in which cycloplegics are of such paramount importance as in astigmatism of a small amount.* The ciliary muscle has formed a bad habit

* The following table shows the relative frequency of small errors:

500 consecutive refractions = 1000 eyes.

Astigmatism	Under 1 D	Under ·5	·12	164	542
			·25	306	
			·37	72	
		·5 and over	·5	108	192
			·62	14	
			·75	70	
	1 D and over				132
No astigmatism					134
					1000

Ophthalmometer correct = 982.

(of which the patient is often quite unconscious), and only gives up this habit when forced to do so by being paralyzed.

Cylindrical lenses correct regular astigmatism of the cornea, and when the error is small, do the work that the ciliary muscle has been doing at so great a cost to the nervous system. When the error is large, certainly when it is over ·75 D, the ciliary muscle cannot correct the defect, and consequently makes no attempt to do so; but the greatest care must be exercised in giving the exact cylinder that corrects the defect, because, if a small portion is left uncorrected, the ciliary muscle can do the rest of the work and strain results. For instance, by retinoscopy we find an eye with the horizontal meridian showing +4, and the vertical +2. We find that a cylinder +2, axis vertical, and a sphere +1, gives $\frac{6}{6}$, and when the effects of the cycloplegic have passed off, we give, say, cylinder +2 axis vertical. Had we been a little more careful we should have found that the best result was obtained by a cylinder +2·25 axis vertical, and this ·25 we have omitted to correct is corrected by the lens, and we introduce eyestrain which did not exist before.

The estimation of astigmatism is now made entirely by (1) the ophthalmometer,* (2) the shadow test, and (3) the final trial of glasses before Snellen's types placed at 6 metres from the patient.

Armed with the knowledge of the refraction of the principal meridians and the direction of the axes, the final test is very easy. The difference between the two meridians represents the strength of the cylinder, and the spherical glass is represented by the refraction of the weakest meridian. Thus, when the horizontal meridian is −4, and the vertical −6, we take a cylinder −2, place its axis to correspond with the least ame-

* This instrument is of the utmost value in correcting small errors; it was correct in 982 cases out of 1,000 (see table, page 135).

tropic meridian—that is, horizontal—and combine it with a spherical glass -4.

In mixed astigmatism the selection of the glasses is a little more complicated.

As mentioned before, the difference in refraction of the two meridians equals the amount of astigmatism. When the horizontal is $+3$, and the vertical -2, 5 D is the amount of the astigmatism. Now, we can use either a concave cylinder and convex sphere or *vice versa*, and sometimes it is as well to try both kinds, as one may be preferred. Let us in this case take a -5 cylinder, and place it in the trial frames with the axis horizontal (*i.e.*, at right angles to the myopic meridian), and correct the hyperopia with a $+3$ sphere. When the patient recovers from the cycloplegic, this sphere will have to be reduced to $+2$, or even $+1{\cdot}5$. As a general rule it is best to choose the cylinder that corrects the most defective meridian. For instance, the vertical meridian is -1, and the horizontal $+4$. Here select a $+5$ cylinder, set vertically, combined with a -1 sphere, which may have to be strengthened to $-1{\cdot}5$ when the cycloplegic has passed off.

The optician should be instructed to set the concave glass next the eye, in order to obtain a periscopic effect.

The rule in mixed astigmatism is: The cylinder represents the difference between the two meridians, with its axis at right angles to the meridian whose sign it corresponds to, and the spherical glass should be the value of the meridian whose sign is the opposite to the cylinder.

In testing the patient under a cycloplegic 6 metres from Snellen's type with the trial glasses, we may have to add or subtract from the various glasses, sphericals or cylindricals, to get the best result, and the best position of the axis of the cylinder may be a few degrees different from what the retinoscopy or the ophthalmometer indicated; but we must remember that the

subjective examination must always have the "last word," the objective examination being our guide, and never our master.

Another important rule to be observed in the treatment of astigmatism is that it should be *fully corrected*, and when the patient has recovered from the cycloplegic neither the power nor the axis of the cylinder should be altered, although we may have to deduct from or add to the spherical lens. The exceptions to this rule are few, and are as follows: (1) In children under seven years of age, when the astigmatism is less than ·5, no cylinder need be ordered if no symptom of eyestrain be present; (2) in patients over, say, 40 years of age, who have never had their astigmatism corrected and who require a high cylinder, as this latter may give discomfort at first, a

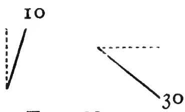


FIG. 68.

slight reduction may be made in the power, but the full correction should be given as soon as possible later.

In examining patients for astigmatism, atropine should be previously used up to the age of 25, and even up to the age of 35, if a low error is suspected; homatropine is sufficient for older patients; after 50 no cycloplegic is necessary.

In ordering cylinders be careful to indicate accurately the axis. If this is done by simply writing down the degrees, a mistake may occur, as there is no uniformity at present in the numbering of the trial frames or prescription forms. The International Ophthalmic Congress at Naples, 1909, suggested that the nasal extremities of the horizontal line should be zero, the temporal extremities 180°, and the vertical line 90°, but this has not yet been universally adopted. The simplest

method is to indicate the axis in degrees from the vertical or the horizontal, as in Fig. 68, or on an optician's form, or, better still, on a form engraved or stamped on the paper, as in Fig. 69.

NOTE.—So important is it, when treating small errors of astigmatism, to correct even the smallest amount, that the trial case should be fitted with cylinders representing fractions of ·12 up to 1 D—*i.e.*, in addition to ·25, ·50, ·75, there should also be ·12, ·37, ·62, and ·87 cylinders.

Irregular Astigmatism.—Physiological irregular astigmatism is present in all lenses. It is due to separate sectors of the lens having a different refractive power, and is infinitesimal in amount. It is this condition

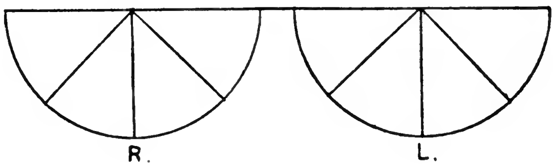


FIG. 69.

which causes a bright star to appear as a radiating figure instead of a bright point.

Sometimes the refractive power of the separate sectors of the lens is so great that several images of a point are formed, and it is in this way we get monocular polyopia in incipient cataract.

Irregular Astigmatism in the Cornea may be considerable, and is generally the result of disease, such as ulcers, nebulæ, wounds, and conical cornea. It is due to a difference in curvature in different parts of the same meridian, and often produces distortion of objects, which regular astigmatism rarely does.

Irregular astigmatism is diagnosed by—

1. *The Ophthalmometer.*—This is the readiest and the easiest method. The reflection of one or both mires is

distorted, and this distortion and the relative positions of the mires vary irregularly in different positions of the arc.

2. *Retinoscopy.*—There is no definite shadow, or, if it be present, it behaves in an irregular manner, and glasses produce no definite and regular effect.

3. *Placido's Disc* (Fig. 70).—This is a round disc supported by a handle. The disc is about 7 or 8 inches

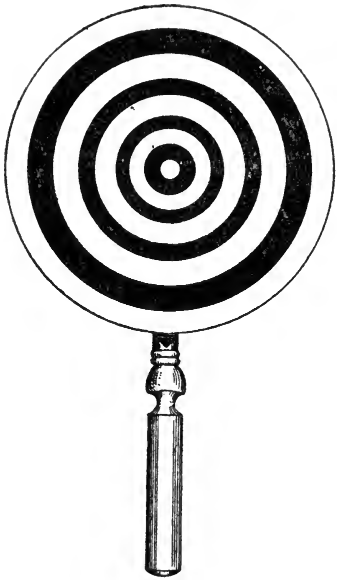


Fig. 70.

in diameter, and has painted on one side alternate concentric rings of black and white, and has a small hole in the centre. The patient stands with his back to the light, and the disc is held by the surgeon a short distance from the patient's eye in such a manner that an image of the rings is thrown on to the cornea to be examined, the patient being directed to look at the

centre. Looking through the central hole, the surgeon sees a diminutive image of the rings on the cornea, and if the latter is normal the rings are round and evenly separated. In regular astigmatism the image appears elliptical, the long axis corresponding with the meridian of least curvature; but when irregular astigmatism is present, the rings are " crinkled " and distorted.

Treatment.—Place before the eye in a trial frame an opaque disc with a small central opening (stenopaic disc), shift the position of the opening, and also place up different lenses. If vision be improved, prescribe stenopaic spectacles, with the lens if indicated; and if the opening be eccentric, specify the amount of decentring.

In conical cornea this treatment is sometimes beneficial, but, unfortunately, in most cases the spectacle treatment of irregular astigmatism is useless.

As regular astigmatism may also be present, it is worth while making the above examination with a stenopaic *slit,* turning it round in different positions to see if any improvement results with or without the addition of a convex or concave spherical lens; and if any improvement results with a lens, the prescription of the equivalent cylinder may improve vision.

If the defect is caused by a corneal nebula, and especially if the patient is young and the opacity not too dense, considerable improvement sometimes follows the use of the yellow oxide of mercury ointment, a small piece of which should be rubbed into the cornea by massage through the upper lid, about twice a week.

CHAPTER IX

PRESBYOPIA

The Influence of Age upon the Accommodation.—In quite early youth the crystalline lens is practically a small bag of semifluid jelly, and accommodation takes place by its being squeezed by the action of the ciliary muscle in such a manner that its antero-posterior diameter is enlarged (see page 31). So great is this "squeezability" (if I may use the term) in the very young, that an accommodative power of 20 D can often be recorded. As age advances, a hardening process or sclerosis goes on in the lens as in all the other tissues of the body, and so its "squeezability" becomes less and less until a point is reached when the near point of accommodation, which represents the fullest accommodative power, has so far receded that the normal eye requires assistance in the shape of a convex lens in order to see near objects distinctly. This is presbyopia.

At the age of 10 years the average **emmetrope's** near point is 7 cms. from the eye, and his far point being at "infinity," we see that his amplitude of accommodation is 14 D (in Fig. 71, in the first column on the left, there are 14 divisions between *p* and *r*), whereas at the age of 30 his near point has receded to 14 cms., and his amplitude of accommodation is then only 7 D—that is, in twenty years he has lost half of his accommodative power.

The same happens whatever the refractive condition of the eye. For instance, a **hyperope** of 4 D (Fig. 72) at

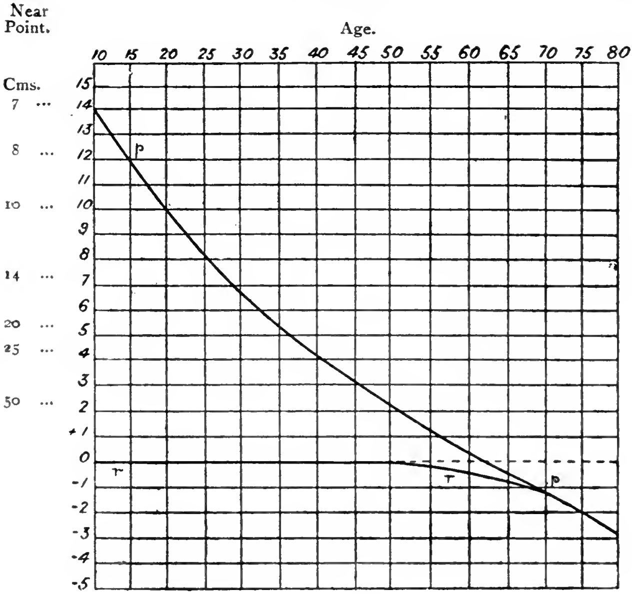


FIG. 71.*

Showing the range of accommodation of an emmetrope at different ages.

the age of 10 has his near point 10 cms. from the eye, and $p = \frac{1 \text{ metre}}{\text{P}} = \frac{100}{10} = 10$ D, r is negative, and

$$\begin{aligned} a &= 10 - (-4) \\ &= 10 + 4 \\ &= 14 \text{ D.} \end{aligned}$$

Again, at 30 we see (Fig. 72) that $p = 3$ D, P being now 33 cms. from the eye, and

$$\begin{aligned} a &= 3 + 4 \\ &= 7 \text{ D.} \end{aligned}$$

* The numerals above represent years, those on the left dioptres. The line p p represents the curve of the punctum proximum, and the line r r that of the punctum remotum.

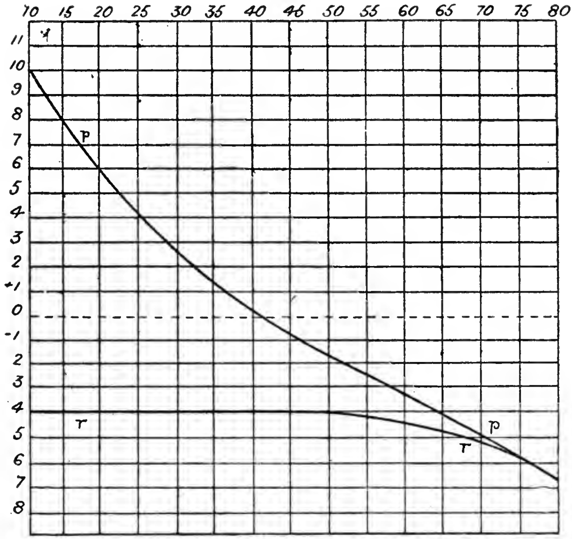


FIG. 72.

Showing the range of accommodation of an uncorrected hyperope of 4 D at different ages.

A **myope,** say, of 3 D (Fig. 73) has his near point, at the age of 10, 6 cms. from the eye, and *p* = 17 D.

$$a = 17 - 3$$
$$= 14 \text{ D.}$$

At the age of 30 we see by the diagram that *p* = 10 D, for P = 10 cms., and R is still 33 cms. on the positive side; hence

$$a = p - r$$
$$= 10 - 3$$
$$= 7 \text{ D.}$$

Whatever the static refraction of the eye, *r* remains stationary till about the age of 55, when we see that in

all three diagrams it begins to curve downwards, showing that the emmetrope becomes hyperopic, the hyperope more so, and the myope less so. This is called *acquired hyperopia.* A point is finally reached when *p* and *r* unite—in other words, when all accommodation ceases; this is about the age of 75; but in emmetropia and

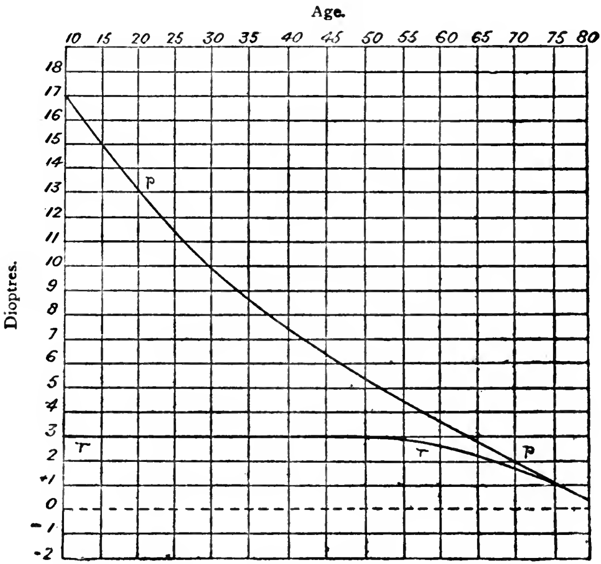


FIG. 73.

Showing the range of accommodation of an uncorrected myope of 3 D at different ages.

hyperopia the positive part of accommodation—viz., that employed for near objects—ceases at an earlier age. In emmetropia *p* is seen to cross the zero line between the ages of 60 and 65 (Fig. 71) (some accommodation is still left, but it is employed in correcting the "acquired hyperopia"), and in hyperopia even earlier. The greater the degree of hyperopia, the earlier will *p* cross

the zero line. In the case of a hyperope of 4 D (Fig. 72) this happens between the ages of 40 and 45—that is, a hyperope of 4 D, when he reaches the age of 42, although he has some amplitude of accommodation, has to make use of it entirely for distance; on the other hand, all myopes of more than 3 D can make use of all their accommodative power for near work (Fig. 73).

These conclusions were arrived at by Donders from a number of observations made and recorded, and the diagrams are the results of the averages of these observations; but we now know that he under-estimated the accommodative power between the ages of 10 and 45, the average power being about 1·5 *more*. This mistake was probably due to a majority of his patients having some latent hyperopia which he was unaware of, as he did not make his patient "emmetropic" before testing the accommodative power.

Duane, in 1909, examined the accommodative power of 600 patients whom he had previously made emmetropic (*Jour. of Amer. Med.*, vol. lii., page 1992), and he gives the following tables:

Age.	Minimum.	Mean.	Maximum.
10	11·2	14	17·5
15	10·5	13·4	16·5
20	9·1	11·5	14·2
25	8·2	10·3	12·9
30	6·8	8·5	10·6
35	5·6	7	8·8
40	4·8	6	7·5
45	3	3·8	4·7
50	1·4	1·8	2·3
55	0·9	1·3	1·6
60	0·9	1·2	1·5

Following on the same lines, I have examined the accommodative power of over 2,000 patients with their refractive error fully corrected, and the chart (Fig. 74) shows the average curve of my results.

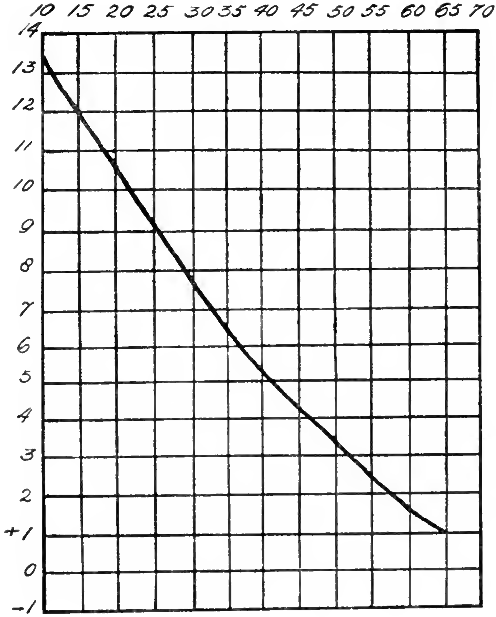


FIG. 74.

My table is as follows:

Age.	Minimum.	Mean.	Maximum.
7–10	9	13·5	18
10–15	7	12	18
20	6	10·5	14
25	5·5	9	13·5
30	4·5	7·5	12
35	4	6·5	10
40	2·5	5·5	8·5
45	2	4·25	7
50	1	3·5	6
55	0·75	2·5	5
60	0·50	1·75	4
65	0·50	1	3

The loss of elasticity of the lens is accompanied by greater firmness and increase in size, and, in later years,

by a loss of homogeneousness and transparency both of the lens and vitreous, which is such a striking condition in youth. The lens reflects more light, and, by oblique illumination, often gives a false idea of cataract. At the age of 45 every individual has, more or less, about 4 D range of accommodation. From our formula $a = p - r$ we get $p = a + r$—*i.e.*, $p = 4 + r$. When the person is an emmetrope we can ignore r; therefore $p = 4$. Now P, the punctum proximum, is $\frac{1 \text{ metre}}{p}$; therefore $P = \frac{1 \text{ metre}}{4} = 25$ cms. That is, the average emmetrope at the age of 45 cannot read nearer than 25 cms., or 10 inches. This may be taken as the presbyopic point.

Donders fixed the presbyopic point at 22 cms., the point to which, he said, the average individual's near point had receded at the age of 40.

As a matter of fact, *there is no fixed presbyopic point.* An individual may be said to have arrived at the presbyopic period when he finds that he cannot do his near work for any length of time without discomfort or some symptom of strain. A long-armed man who does very little near work may not require glasses until the age of 50, whereas a seamstress, with the same refraction and of the same age, may have had to take to glasses five years earlier.

Some writers object to the term "presbyopia," and would expunge it from ophthalmology, giving us nothing in its place. We must have some term to express that condition in which, as the result of the increase of years, the range of accommodation is diminished and the vision of near objects is interfered with.

The recognition of presbyopia is not difficult. When a patient complains that he has to hold his book, when reading, further away than he has been accustomed to, that this is more especially so by artificial light, that the figures 3, 5, and 8 become confused, and that *n* and *u* are difficult to distinguish, and at the same time asserts

that his distant vision has not altered, we may be almost certain we are dealing with a presbyope.

When a patient whose near point has receded, say, to 33 cms. attempts to read or work at that distance for any length of time, symptoms of eyestrain will be sure to supervene. It is a fact that we get from everyday experience, that the full power of a muscle can be exercised only for a very short time without fatigue. A person whose near point is at 33 cms. is using the whole power of his ciliary muscle in order to focus an object at that distance on his retina, and fatigue of the muscle will very soon ensue. This fatigue causes the muscle to relax, it cannot contract to its full extent; vision then becomes hazy, and becomes distinct again only when the object has been further removed from the eye. At the same time the patient will probably complain that, after reading some little time, headache comes on, and the eyes begin to water; these temporary symptoms of eyestrain will pass into chronic symptoms in time, and the red, irritable-looking, watery eyes of middle-aged people are often due to this cause.

Treatment.—Two classes of patients come for treatment. One class simply requests glasses for reading (some of these have been to an optician and have themselves selected a weak spherical glass which proves unsuitable); the other class comes complaining of some symptom of eyestrain, and they may or may not be aware that they require glasses.

A cycloplegic is rarely necessary (except in isolated cases where our results are unsatisfactory or we wish to examine the lens for cataract), because ciliary spasm is very unlikely to be present, and there is no latent hyperopia, it having all become manifest. We first ascertain the distant correction, and then the near point of distinct vision and the most comfortable distance for reading or working. Suppose distant vision is normal and the punctum proximum is 28 cms., and

the distance at which the patient wishes to read is 33 cms., his amplitude of accommodation is $\frac{100}{28} = 3\cdot5$ D; to avoid fatigue he must not use the whole of this, but must keep about $\frac{1}{3}$ in reserve. Let him have 1·5 D in reserve; this leaves him 2 D available accommodative power, and, as he requires 3 D, we supply the deficit by giving him +1 D glasses.

The treatment, simple as it appears, is not always successful, because the accommodative power varies with the individual, and when it is low a greater reserve has to be left. We generally find that an emmetrope of about 48 requires a reading glass of +1 D, and an additional +1 for every five years.

Perusal of the table on page 147 shows what a wide difference there is in the accommodative power of different individuals; when the accommodative power is lower than normal it will be found that the individual is older, and looks older, than his age, and *vice versa*. Premature presbyopia, which is really premature senility, is provoked by various conditions, but intestinal stasis is perhaps the commonest cause. A small error of refraction uncorrected not only tends to lower the power of the ciliary muscle by the constant drain on its energy, but also tends to hasten the sclerosing processes in the lens (see page 163).

When ametropia is present, the distance correction must be ascertained, and the presbyopic glasses added to it; thus, if the distance glass is +2, and an addition of +1·5 is required for reading, the reading glass is +3·5; if the distance correction is − 4, and an addition of + 2 is required for reading, the reading glass is − 2. When astigmatism is present, the correcting cylinder must, of course, be added.

It was the custom until quite recently for presbyopes who had fairly normal distant vision to be provided with reading glasses only, but we now recognize the importance of correcting all errors of refraction, especially at this period of life, so that unless the patient is an emmetrope he will require glasses for distance as well as near work. This double correction is best prescribed in the

form of "bi-focal" spectacles or pince-nez (see page 17), where the upper part is used for distance and the lower for reading. These bi-focals are now made so that the division between the two portions is invisible,* and it is not an exaggeration to assert that they have completely revolutionized the treatment of presbyopia.

They should be prescribed for all patients who have the slightest error of refraction in addition to their presbyopia, if they show any sign of eyestrain or nerve waste. On the other hand, those who live an open-air life, whose distant vision is practically normal, and who enjoy good health, may be allowed to have reading glasses only.

As the bi-focals have to be used for writing as well as reading, it is very important that the lower section be not too strong. It is rarely necessary at any time of life to wear a stronger addition than 3 D; should the patient want a stronger reading glass for the evening, it must be prescribed as a separate glass. As an alternative to bi-focals, the reading "addition" may be mounted in pince-nez or "hook fronts," to be worn in front of the distance glasses when reading. When so-called "music" glasses for near work at arm's length are required, they should be +1 or +1·5 D weaker than the reading glasses.

Fatigue of the Accommodation.—We must be careful to distinguish between presbyopia and ordinary physiological fatigue of the ciliary muscle, which may come on after prolonged use of the eyes in the normal, or may be associated with general muscle fatigue, as in neurasthenia. As we have seen, presbyopia is not necessarily due to weakness of the ciliary muscle, but to the sclerosing of the lens.

* The optician must take great care in fitting and centring bi-focals; the division between the glasses should never be higher than the margin of the lower lid, and full allowance should always be made for convergence—thus, if the patient converges 3 mms., then each reading portion should be decentred in 1·5 mms.

CHAPTER X

ANISOMETROPIA

ANISOMETROPIA is a condition in which the refraction of the two eyes is different. A difference in refraction in the two eyes is more often met with than absolute equality, and in astigmatism it is very common to find a difference of ·25 or ·50 between them.

It was formerly the practice only to recognize anisometropia when, to produce the maximum of visual acuity in the two eyes, different glasses were required; but the increased knowledge we have now of the effects of eyestrain has taught us that the smallest amount must not be neglected, and, further, that the smaller the amount of anisometropia, the more important is it to correct it.

Every possible combination may exist:

1. One eye may be emmetropic, and the other ametropic.

2. Both eyes may be ametropic—

    (*a*) The same variety of ametropia, but unequal in degree;

    (*b*) Different varieties of ametropia, one eye myopic and the other hyperopic; this variety is sometimes called "antimetropia."

When one eye is astigmatic and the other hyperopic or myopic, the astigmatic eye has generally the same form of ametropia as the non-astigmatic eye, and very often one of its meridians has the same amount of ametropia.

Except when it is the consequence of an operation, loss of lens, etc., anisometropia may be regarded as congenital, and attributable to the unequal development of the eyes.

The difference of the refraction of the two eyes may be very great, and is then often associated with marked asymmetry of the face; a difference of 10 dioptres has been recorded.

Varieties of Anisometropia.—There are three varieties of anisometropia:

1. Simultaneous binocular vision exists.
2. The eyes are used alternately.
3. One of the eyes is permanently excluded.

1. Simultaneous Binocular Vision — *Tests for Binocular Vision*—(*a*) *The Prism Test.*—The patient fixes an object at a distance, and a strong prism, base in or out, is placed before one eye, the other being uncovered; at the moment of interposing the prism, if the eye make a movement towards the apex of the prism, binocular vision exists.

(*b*) *Snellen's Coloured Glass Test**—"*Friend*" *Test.*—This apparatus consists of a frame, hung up before the window, in which letters of coloured glass, alternately green and red, are placed. The patient standing in front of them, at a distance of 4 or 5 metres, is provided with a spectacle frame into which one red and one green glass is placed, the colour of these glasses being of the same intensity as that of the letters. Only the red letters can be seen through the red glass, and the green letters through the green glass, so that each eye, separately, only sees half the letters. The letters in the frame may be made to spell a word, such as F R I E N D, so arranged that the letters F, I, and N are red, and R, E, and D green. If the patient, having had

* This test was introduced into England from Donders' clinique in 1881 by the author.

any ametropia corrected, sees all the letters and spells the word "friend," we know he has binocular vision; but if, *e.g.*, he only spells F I N, we know that he is using the eye with the red glass in front of it, and that the other eye is excluded from vision.

For binocular vision to exist in anisometropia the difference in refraction between the two eyes—that is, the degree of anisometropia—must be small, although cases have been recorded where it has amounted to 6 D. Under these circumstances, although the magnitude and acuteness of the images in the two eyes are unequal, they overlap and help each other.

If each ciliary muscle could act independently, the anisometrope could very often correct each eye by a separate and independent accommodation in each eye; but it is generally believed that the same effort of accommodation is made on both sides, with the result that only one image is sharp. At the same time, it should be noted that when the anisometropia is of low degree, some patients may have the power of producing asymmetrical accommodation to a limited extent. If we place a convex glass of +·50 in front of one eye and a concave glass of −·50 in front of the other, and thus produce an anisometropia of 1 D, and attempt to read with the glasses, a very distinct feeling of strain is experienced; but whether this strain is brought about by actual asymmetrical accommodation, or only by the attempt to produce it, it is difficult to say.

Treatment.—The treatment in these cases varies considerably. In quite young patients, unless the difference between the eyes is very great, the full correction of each eye should be ordered in accordance with the plans stated in the previous pages. In older patients we must try the binocular effect before prescribing glasses. The full correction in each eye is especially indicated when marked symptoms of eyestrain exist, and in these cases, although the treatment may be complained of at first,

it is wise to insist upon it, and in many cases the discomfort produced at first by the glasses disappears in a few weeks, and eventually the symptoms of eyestrain disappear. On the other hand, patients who have lived many years without having their anisometropia corrected, have become so accustomed to the difference between the eyes that the removal of this difference not only confers no benefit, but proves irksome, and they may complain of dazzling, giddiness, and headache.

Place the proper correction in front of each eye, and try the binocular effect; if this is unsatisfactory, take off a little from the stronger glass or add a little to the weaker, or do both. Sometimes we find that the patient prefers the same correction in both eyes, and that this correction is weaker than that required by the more ametropic eye. For instance, suppose the right eye is emmetropic and the left hyperopic to the extent of 2 D, we try first a plane glass in front of the right and +2 in front of the left; if this causes discomfort, we may try a +·5 in front of the right and +1·5 in front of the left. If this is still uncomfortable, we try +1 in front of both eyes. No definite rule can be laid down; each case should be treated according to its requirements and the patient's sensations.

It is a good plan when the correction has been found under a cycloplegic to deduct a little more from the more ametropic eye and a little less from the other. For instance, supposing under atropine the refraction is, right eye +2, and left eye +3·5; we give +1·25 for the right, and +2 for the left. When the difference between the glasses is great, the patient should be taught to turn his head when looking to the right or left, and not his eyes, so that he is always looking through the centre of his glasses. If he does not look through the centre of his glasses, a prismatic effect is produced; this, of course, will produce an artificial heterophoria and cause strain. Mr. W. A. Dixey has suggested that

this prismatic effect on looking eccentrically can be avoided by reducing the margin of the stronger lens to the power of the weaker one in myopic patients, where the difference in the two eyes is marked and binocular vision exists. For instance, the right eye is -2 and the left -6; the outer margin of the -6 lens is reduced to -2, as in Fig. 75.

2. THE EYES ARE USED ALTERNATELY.—One eye is emmetropic or slightly hyperopic, and is used for distance, and the other myopic, and used for near work. If eyestrain be not present, the patient may prefer to have no glasses. Although he has lost binocular vision,

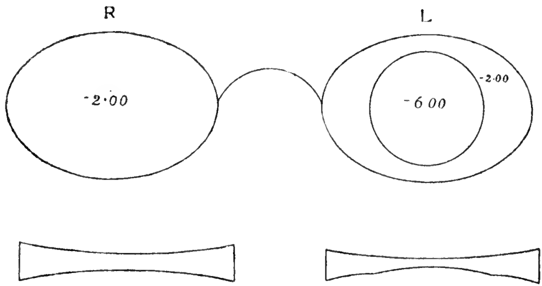


FIG. 75.

he has gained other advantages; in some cases he can entirely dispense with muscular effort, his ciliary muscle and internal recti being rarely used. If eyestrain be present, we must prescribe glasses after ascertaining the binocular combination that suits best. We sometimes find that if, for instance, both eyes are hyperopic, the patient prefers the same glass in both eyes corresponding to that required by the most ametropic; this latter eye will then be used for distance and the other for near work. In the same manner, if both eyes are myopic, we give each the correcting glass of the weaker.

In all these cases the cylinder should never be altered,

except in rare instances where there is a great difference in the astigmatism of the two eyes, and then the stronger cylinder may have to be reduced.

3. One Eye is permanently excluded from Vision.—When the difference between the eyes is great, the more defective eye is little used, and tends to become amblyopic, if it is not so already. In such cases we must give each eye its proper correction, and instruct the patient to practise the amblyopic eye by totally excluding vision with the good eye by covering it with a patch for a certain time every day. In "amblyopia ex anopsia," occurring in young patients with convergent strabismus, this treatment, patiently persevered in, is often most satisfactory.

The defective eye may never take its proper place in binocular vision, but in some cases it may become very useful, especially if any damage or disease should affect the good eye; and, moreover, the cosmetic effect which sometimes occurs is considerable, for, if treated in time, the strabismus which so often appears in these cases may be prevented.

Adults with only one useful eye may be allowed to wear a monocle, provided that the correction does not include a low-power cylinder. If a cylinder is required, the glass must always be placed in the proper position; and if a high cylinder is used, the patient can tell at once if the axis of the cylinder has been properly adjusted. But in a cylinder of ·25 or ·5 it will be impossible for him thus to judge the correctness of the axis, even though he thinks he is putting the glass into its proper position. In such cases, if a monocle is insisted upon, the cylinder should be omitted.

Monocles should be mounted in a frame with a bracket, in order that the glass may be removed from contact with the skin and lashes.

Presbyopia and Anisometropia.—When presbyopia is present with anisometropia, we should, whenever pos-

sible, prescribe bi-focal glasses. The lower reading section must be found by the same kind of trial as we made for the distant correction. It does not follow that the same addition is given to each eye. For instance, one eye has a hyperopia of 2 and the other of 4, and the patient is 52; we should try +4 and +6 for reading, or, if this be not comfortable, +4·5 and +5·5, or +5 in both eyes.

When one eye is permanently excluded, and the remaining eye is ametropic and presbyopic, as in aphakia after cataract extraction, reversible spectacles are useful; the distant correction is on one side and the reading on the other. When the patient is walking, the distant correction is in front of the "good" eye and the reading glass in front of the useless eye, and when he wishes to read he reverses the spectacles, and so brings the reading-glass in front of the good eye, the bridge being made to fit the nose in either position.

When the difference between the two eyes is marked, and simultaneous binocular vision exists, although the distance correction is accepted, discomfort may come with near work. This is due to the production of an artificial hyperphoria. Let us suppose the right eye to have a myopia of 1·5, and the left a hyperopia of the same amount. When reading and looking, say, 6 mm. below the optical centres, the patient is looking through a prism 1° base down in front of the right eye and 1° base up in front of the left. (A lens 1 D, decentred 8·7 mm., produces a prismatic effect of 1°.) The difficulty can be overcome by cementing on the lower portion of each lens the necessary correcting prism. In the above case a prism 1° base up in front of the right eye and 1° base down in front of the left will correct the hyperphoria.

When a presbyopic correction is also required, the prismatic effect may be obtained by decentring, or by making the prism convex to the amount required.

CHAPTER XI

APHAKIA

ALTHOUGH, to be quite correct, aphakia denotes an eye without a lens, the latter having been purposely removed by operation, or accidentally lost through a perforating wound or ulcer, we generally include under aphakia, conditions in which the lens is more or less completely dislocated (as in the old operation of "couching"), so that rays of light passing into the eye do not intercept any portion of it.

The absence of the lenticular images, found by holding a light near to the eye (see page 31), and a tremulous iris, are characteristic signs of this condition.

A strong convex glass must be placed before the eye to obtain distinct distant vision, unless the original condition of the eye was one of high myopia. A convex glass of 11 or 12 D, placed about 13 mm. in front of the eye, is about the equivalent of the crystalline lens; but, "as the refracting system of the eye is now entirely different from that of an ametropic eye, the tests of visual acuteness are no longer comparable with that of normal eyes. The retinal image in an aphakic eye is 1·33 times larger than in a normal eye. Hence vision of $\frac{6}{9}$ in a corrected aphakic would really only correspond to a visual acuteness of $\frac{6}{12}$ in a normal eye" (Percival).

As all accommodation is lost through the removal of the lens, the convex glass has to be increased in strength for near work, according to the distance of the near work from the eye; thus, if 33 cms. is the spot required

at which to read, +3 must be added; and if 25 cms. is the distance, +4 must be added. After cataract extraction there is almost always a large amount of inverse astigmatism, and a + cylinder of 1 to 2 D, placed horizontally, or nearly horizontally, will probably be required. As this inverse astigmatism is generally fairly high immediately after the operation, and gradually diminishes during a period of two or three months, it is wise not to prescribe the cataract glasses until this period has elapsed.

When a cylinder is required, the glass is best given in the sphero-toric form (see page 16).

When the original condition of the eye was one of ametropia, the following formula is a fairly accurate guide of the glasses required after operation (Percival):

$$D' \approx^{*} \frac{25 + D}{2 - \frac{D}{100}},$$

where D is the original refraction of the eye and D′ is the approximate glasses required; thus, if D = −15, then

$$D' \approx \frac{25 + (-15)}{2 - \frac{-15}{100}} = \frac{25 - 15}{2 + \cdot 15} = \frac{10}{2\cdot 15} \approx +4\cdot 65;$$

and if the original refraction was a hyperopia of 6,

$$D' \approx \frac{25 + 6}{2 - \frac{6}{100}} = \frac{31}{2 - \cdot 06} = \frac{31}{1\cdot 94} \approx +16 \text{ D}.$$

This formula is calculated for the position of the correcting lens D being 13·7 mm. in front of the eye; if this distance is increased, the convex glass is proportionately decreased in strength. For practical purposes, if we halve the amount of the original error and add to it +11, we shall find that this is approximately the glass required. According to this, if the patient had

* This sign represents approximate equivalency.

originally a myopia of 22, he probably requires no distance glass after the removal of the lens.

The most convenient form of glass is the bi-focal (see page 16). Some patients prefer the reversible form (see page 158).

If the correction be not satisfactory, an examination of the patient in the dark room with focal illumination and a strong lens, will probably reveal an opaque capsule, which will require needling before any good result is obtained with glasses.

CHAPTER XII

EYESTRAIN

EYESTRAIN, as we now understand it, extends over a far wider field than it did even twenty-five years ago, and the list of troubles which more or less depend upon its presence grows larger every year. It includes, of course, the old "asthenopia" that Donders, writing in 1858, considered was due to hyperopia, and the "muscular asthenopia" which Von Graefe, a few years later, attributed to strain of the internal recti muscles. The word "asthenopia," by its derivation, denotes weak sight, which, in the large majority of cases, does not exist; and even if we take the broader meaning, implying tired sight, the word is equally inappropriate. It is therefore best to restrict the term "asthenopia" entirely to retinal fatigue—*i.e.*, retinal asthenopia—with which we are not here concerned.

Eyestrain may be defined as a symptom or group of symptoms produced by the correction or attempt at correction by the ciliary muscle of an error of refraction or a small amount of anisometropia, or as a want of balance between the external muscles of the eye. Where gross errors exist, either in the refraction or the anisometropia or in the muscular equilibrium, the patient cannot correct, and consequently makes no attempt to correct, the defect, and eyestrain is not produced. The smaller the error, the more likely is eyestrain to be present, and also, unfortunately for the patient, the more likely is it to be overlooked.

The symptoms of eyestrain may be grouped under three headings:

1. Manifestations on the eye and lids.
2. Peripheral irritation.
3. Nerve exhaustion.

1. **Manifestation of Eyestrain on the Eye and Lids.**—Eyestrain means an increased demand for work on the part of the ciliary or external muscles, which determines an increased flow of blood to these parts; if this is constant, congestion is liable to follow, and with it pain.

With the parts thus rendered specially receptive to infective germs, there is little difficulty in understanding that inflammation should ensue, and thus we find that blepharitis, conjunctivitis, corneal ulcers, phlyctenulæ, iritis, cyclitis and glaucoma may have eyestrain as one of the predisposing causes. There is also little doubt that cataract may be started by the irregular contraction of the ciliary muscle in correcting low errors of astigmatism, and that the correction of these errors, with the consequent disappearance of the eyestrain, will stay the progress of this disease.

2. **Peripheral Irritation**—

(*a*) With pain.
(*b*) Without pain.

Peripheral Irritation with Pain.—In the same manner that a decayed molar may produce neuralgia by peripheral irritation, so eyestrain may produce headaches, or any other form of peripheral irritation. Headache is by far the commonest symptom of eyestrain. So common is it, indeed, that no physician should attempt to treat a patient for constantly recurring headaches unless the existence of eyestrain has been eliminated by proper correction under a cycloplegic.

The position and character of the headache form no guide to the cause, for ocular headache may be of any possible variety. It may simply amount to a slight

aching over the eyes or at the back of the orbit. It may be a frontal headache. Sometimes it originates and remains limited as a vertical or occipital pain, or it may originate in the brow, and pass to the vertex and occiput, and pass down the spine. It may be unilateral as a typical hemicrania, and may be indistinguishable from a true migraine attack.

There is no rule as to its position; this varies with the individual. In some it is superficial, akin to neuralgia; in others, deep-seated.

It may be a dull, heavy ache, difficult to localize accurately, or it may be a sharp, shooting, lancinating pain, that seems to originate in a tender spot on the scalp or forehead. Some describe the pain as an opening and shutting of the skull, others as if a nail were being driven into the vertex.

But the commonest form of eyestrain headache is a pain over one or both brows, often termed "brow ague."

Again, the time of the headache varies; it may be a permanent headache or periodic, and it may appear to have no direct association with excessive use of the eyes.

Early-morning headache is a very common form of ocular headache, and this astonishes most patients, as they imagine that the night's rest should have removed the possibility of this.

To explain the periodicity of the headaches we have to remember that the cause of the headache may be multiple. There may be two, or even three, factors present. A patient who suffers from a periodical headache may have eyestrain, a gouty or other diathetic tendency, and at times, added to these, some special nerve depressant, such as worry or trouble.

Now, each of these factors, or possibly any two, may not suffice to cause a headache; all three must be present, and only at such times as all three are present is the headache there. If the eyestrain be removed by

correcting the error, the other causes, save under exceptional conditions, will never succeed in producing the pain.

It is important to remember that with this headache there is often associated nausea, and even vomiting. The so-called *bilious headache* of the " old school " is generally an ocular headache.

The intimate relation of the nerve-supply of the ocular muscles with the fifth nerve, and the association of the latter with the sympathetic and pneumogastric, explain the method of origin of the symptoms.

The ciliary muscle and the external eye muscles, when strained, demand an increased supply of blood, which in time leads to congestion. This in its turn will not be limited to the strained part, but will spread to other parts of the eye, causing the watery, red eye already alluded to. The pain of " fatigue " is probably due to this congestion, and accounts for the tender eyeballs so common in migraine.

Liveing says that the nerve-storms in migraine have their point of departure or principal focus in the optic thalami, and that the normal course is from above downwards to the nuclei of the vagi, and from before backwards in the sensory tract, thus explaining the peculiar visual phenomena, such as teichopsia and other symptoms of ophthalmic migraine.

Of course, there are cases of true migraine, when the " point of departure " is from above downwards, but a very large percentage of cases labelled " migraine " are purely *ocular* in origin; and if the error of refraction is corrected, or the muscular equilibrium re-established, the symptoms disappear.

The connection of the fifth nerve with the sympathetic enables us to understand how the peripheral irritation of eyestrain can pass to the dura mater, pia mater, and sensory layer of the brain cortex.

Gowers says: " If the sensory cells of the cortex, in

which the cranial and intracranial sensitive structures are represented, are the most readily influenced of all the sensory cells, we can understand that headache should result from vascular repletion."* Everyone knows from experience that a headache increases sometimes to an alarming severity when the head is lowered—*i.e.*, when more blood flows to the head.

As we have already seen, although in eyestrain the peripheral irritation, if it takes the above form, is always or almost always present, it may not manifest itself as a headache unless there is a general increase of blood-pressure. If the blood-pressure be lowered by general treatment, the headache will disappear. But this does not mean that the headache was not ocular in origin. It simply means that one of the factors causing the pain has been removed, and the other, or others, are not sufficient to cause it.

It is therefore a good rule never to attempt to treat a headache as a migraine without previously eliminating eyestrain.

Peripheral Irritation of Eyestrain unaccompanied by Pain.—The chief types of this form of eyestrain are epileptic attacks and choreiform movements of the facial muscles.

It is important to remember that it is not the error of refraction that causes the peripheral irritation, but the unconscious correction of the error by the patient. When the defect is great, no attempt is made to correct it, as the ciliary muscle can only correct low degrees of astigmatism; hence there is no eyestrain.

It is only a cycloplegic that will reveal this unconscious correction; hence no eyes can be reported as normal unless carefully examined under atropine or homatropine.

The removal of eyestrain does not, in the strict sense of the word, cure epilepsy any more than it cures a

* "Nervous System," vol. ii., page 795.

headache, but by removing the eyestrain we remove one of the causes, and frequently the only cause, that determines an attack. An epileptic attack and some forms of headache only differ in degree; they are "nerve-storms."

The foregoing remarks apply equally to those so-called choreiform movements, tics, and habit-spasms which are so distressing to children and young adults, which take the form of spasmodic involuntary twitching of the facial muscles.

Constant blinking of the eyes in children should always make one suspicious of the presence of eyestrain.

In all such cases it is most important to eliminate eyestrain. Such cases are purely functional, and it is not too much to say that a pair of suitable glasses will immediately alleviate, and not infrequently cause a complete cessation of, the symptoms.

Vertigo as a symptom of peripheral irritation may exist, but its commonest manifestation is in connection with diplopia.

Nausea and vomiting have already been mentioned in connection with ocular headache; they may exist without headache, and apart from diplopia and vertigo, and may be due to eyestrain. Their presence is explained by the intimate association of the fifth with the vagus.

As an instance of the variety of form which peripheral irritation, through eyestrain, may assume, *hyperhidrosis* must be mentioned.

3. **Nerve-Power Waste; Nerve-Exhaustion; Neurasthenia; Brain-Fag.**—This is a manifestation of eyestrain that is as common as it is subtle. Subtle it must be, as every possible cause has been cited as the origin of the various groups of symptoms which are exhibited, except the eyes. It has not been sufficiently recognized that in a large majority of those cases called neurasthenia the real trouble is a constant "nerve-power

leakage" or waste of nervous energy, and in a large number of cases eyestrain is the cause.

This "nerve-waste" may exist in a person of robust nervous temperament without much, if any, harm, but in one whose nervous conditions are unstable it must in time show itself. Even perfectly robust individuals showing no symptoms of eyestrain may manifest it when under altered conditions, such as after shock of any kind, or lowering of the general vitality from any cause.

A person with a low degree of astigmatism, or with anisometropia, or want of balance of the ocular muscles, during all his waking hours is sending down impulses to the eye to correct the defect, and when he starts on near work he starts with a big deficit, and further strain results. This must mean great waste of nervous energy.

Writers on neurasthenia agree that the ages when the disease is most liable to show itself are between 20 and 49, and these are exactly the ages when this form of eyestrain is most manifest.

Again, those most affected are almost invariably people who are engaged in constant near work, such as engine-fitters, post-office and bank clerks, teachers, journalists, and professional men and women.

Insomnia is a very prominent symptom of eyestrain, and so a vicious circle is started, eyestrain producing, among other troubles, insomnia, and insomnia in its turn aggravating the patient's condition because the all-important restorative is wanting. The extremely depressing effect of insomnia is a matter of common knowledge, and the depression caused by it has led hundreds to suicide.

The physician who is called upon to treat a so-called "functional nerve disorder," and fails to eliminate the element of eyestrain, fails in his duty both to himself and to his patient, for there is no functional trouble that may not be due to eyestrain.

The depression attending " nerve-waste " may lead to the alcoholic habit, and the irritability so often present in those suffering from functional nerve disorders often induces the sufferer to resort to sedatives, such as morphia.

If the " nerve-waste " is arrested, the depression or irritability is removed, and the drug habit is more easily overcome.

Once we allow that this nerve-power waste may exist, we recognize that there seems to be no limit to the various ailments which may, perhaps gradually, and often imperceptibly, follow.

Dyspepsia and constipation, and other disorders of the alimentary tract, may be caused by eyestrain.* The dyspepsia may be, as we have seen, a direct reflex irritation from the strained eyes through the pneumogastric, and it may also be the result of nerve-power waste; for if this waste causes depression, and the due amount of nerve energy for digestion is not available, then the various digestive processes are interfered with, not only in the stomach, but throughout the digestive tract.

It has been suggested that eyestrain is present in patients suspected of being in the so-called pretuberculous stage, and that by removing the eyestrain the advent of tubercle may be prevented.

This is quite consistent with the above theories, and with the experience of many.

The patient suffering from nerve-power waste has a low resisting power to all disease germs, and is in what one might call a " pre-germ stage," so that he is more liable to any infection than the normal person.

There can, therefore, be little doubt that the correction of eyestrain takes a very prominent place in preventive medicine.

* " Aberrant Dyspepsias," by Leonard Williams. (*The Hospital*, December 12, 1908.)

The chief reason why the eyes are so seldom suspected of being the cause of neurasthenia, brain-fag, and the different varieties of functional nervous troubles, is that the majority of patients have either good sight or they are already wearing glasses which apparently correct their refractive errors.

The enormous importance of correcting eyestrain has been abundantly shown during the war in the number of soldiers suffering from shell-shock, and neurasthenia following on head injuries. The loss of nerve energy consequent on an accident renders it imperative to arrest any further leakage, and the correction of a low error of astigmatism or anisometropia, or, in bad cases, where testing is impossible, the bandaging of one or both eyes, has led to immediate improvement in the whole condition of the sufferer. (*Note.*—It ought never to be forgotten that credit for forcing the attention of the profession to the importance of eyestrain belongs to Gould of America, who brought out his fascinating Biographic Clinics in 1903. Dr. Harwood, in an admirable paper read at the Oxford Ophthalmological Congress in 1917, maintains that the real cause of the troubles grouped as eyestrain, is an instability of the normal tonic contraction of one or both ciliary muscles, and that this instability is produced when, as Weir Mitchell puts it, the brain is sensitized by disease.)

CHAPTER XIII

HETEROPHORIA

It has been shown (page 44) that in ideal binocular vision the visual axes are parallel when the eyes are at rest, E R (Fig. 76, A), and that when the eyes accommodate for a point P, both eyes converge to that point; that in normal vision, if we destroy the possibility of fusion, that convergence lags behind accommodation, and

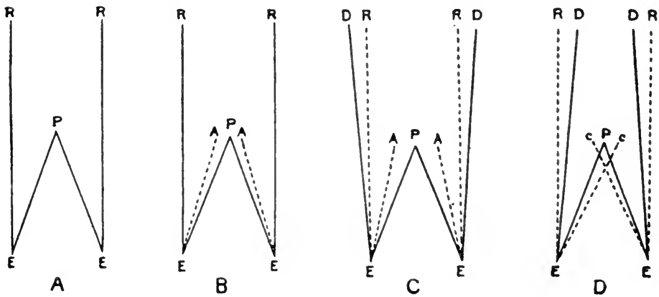


Fig. 76.

instead of converging for P, the visual axes are in the d rection E A (Fig. 76, B), the difference between A and P being the " fusion supplement." We have also seen that if the position of rest is one of divergence (Fig. 76, C), A is further removed from P, and the " fusion supplement " is larger. Now, this position of divergence at rest is caused by " muscular insufficiency," in this case of the internal recti muscles. This means that the

internal recti are insufficient to produce parallelism without active muscular contraction which the demand for binocular vision necessitates during all the waking hours; hence the muscles are never at rest, and when the necessity for convergence arises, the interni start with a deficit of power. The constant using up of part of the convergence power fatigues the internal recti muscles, and the positive part of the amplitude of convergence will be found very much diminished.

The amplitude of convergence may be quite up to the average, but if the positive part of it is too small, this indicates the presence of insufficiency of the internal recti and the liability to eyestrain. Take a patient who has 3 m.a. of latent divergence, and whose convergence near point is 14 cms.: we have—

$$\begin{aligned} ca &= 7 \ -(-3) \\ &= 7 \ +3 \\ &= 10 \text{ m.a.} \end{aligned}$$

10 m.a. of amplitude of convergence would be quite sufficient if it were all positive, but only 7 are positive, and only from $\frac{1}{3}$ to $\frac{1}{4}$ of this power should be used for any length of time, which means that only about 2 m.a. should be used, which would be useless for near work. Remove the insufficiency—that is, remove his latent divergence—and he will not only have 10 m.a. of positive convergence power, but even more, for the constant fatigue of the internal recti, produced by the work of overcoming the latent divergence, will be removed.

"Insufficiency" of a muscle implies that the muscle is relatively weaker than its opponent, so that in static and dynamic vision extra impulses have to pass to that muscle in order to produce perfect fusion.

An insufficient muscle is not necessarily weak. It is insufficient because its opponent through spasm or preponderance (*Uebergewicht*, as Graefe called it) is "too sufficient"; hence in the case of insufficiency of the

interni, although the muscles may be insufficient for convergence, they may be perfectly able to take their part in the associated movements of the eyes to either side.

When a muscle is absolutely weak, it is wiser to employ the term "inefficiency." Thus, convergence inefficiency means inability in the internal recti to act normally, irrespectively of their opponents. A patient suffering from convergence inefficiency appears to have no power to supply a fusion supplement.*

Insufficiency may be present in any of the muscles. If the visual axes at rest are convergent, the external recti muscles are insufficient to produce parallelism (Fig. 76, D). In this case binocular distant vision, which should be perfect rest to the eyes, necessitates the constant contraction of the external recti, and they are liable to become fatigued and to cause eyestrain. During convergence, also, we may find latent convergence, the eyes converging to a point nearer than P (Fig. 76, D), and the necessity for fusion demands contraction of the external recti to overcome this overaction of the interni: hence fatigue. And so with the other muscles. If one muscle by spasm or preponderance over its opponent prevents the eyes from assuming the normal position when at rest, there is liability to fatigue and eyestrain; whether it manifests itself or not (there are a large number of cases of insufficiency which never produce any symptoms) depends entirely on the amount of insufficiency and the nervous condition of the individual.

When we consider that on the *relative* strength of the muscles of the eyeball depends the position of the eye, and that the smallest amount of preponderating strength or the slightest amount of weakness of one muscle will

* Landolt calls the eyestrain produced by the first variety (insufficiency) "peripheral motor asthenopia," and that produced by the second variety (inefficiency) "central motor asthenopia."

cause a displacement or a tendency to displacement (*i.e.*, a latent deviation) of the eyes, we can only wonder that the condition of parallelism of the visual axes in distant vision is so constantly found. The secret is, that the desire for binocular vision, obtained by the fusion of the two images, acts as an unconscious stimulus to the weaker muscle, and masks the relative weakness. If binocular vision be impossible through the sight of one eye being very much inferior, then the stimulus is absent, and the eyes assume a divergent or convergent position of rest, which becomes manifest, and is then a squint. In other words, the heterophoria passes into a heterotropia. We must be careful not to use the term "insufficiency" in connection with squint; it is quite unnecessary, and causes a great deal of confusion to apply the term to, for instance, an atrophied internal rectus in an old divergent strabismus. An insufficiency, if unrelieved, may pass into a squint, but they are two distinct things.

In estimating insufficiency of a muscle we must beware of attaching too much importance to *one* examination; a muscle may be insufficient at one time and not at another.

The following terms, suggested by Stevens of New York, are now in common use in designating the different forms of insufficiency (see plate, page 45).

Orthophoria = visual axes parallel, and lying in the same horizontal plane.

Heterophoria = visual axes not parallel or not in the same horizontal plane; divided into:

1. Exophoria. The eyes tend to turn out; insufficiency of the interni.
2. Esophoria. The eyes tend to turn in: insufficiency of the externi.
3. Hyperphoria. One eye tends to be on a higher level than the other, due to insufficiency of the superior or inferior rectus.

4. Insufficiency of the oblique muscles—

(*a*) Hyperesophoria, a tendency up and in.
(*b*) Hyperexophoria, a tendency up and out.

5. Cyclophoria.

1. **Exophoria** (*Insufficiency of the Internal Recti—Convergence Strain*).—"**Convergence Insufficiency**" is a latent external squint, overcome for the time by the strong desire for single vision.

Strain of the internal recti is essentially dependent upon binocular vision, and persons who have not the advantage of binocular vision, by a compensation of Nature cannot suffer from this trouble.

Tests for Insufficiency of the Interni.—It has been shown that the Maddox test is the best and simplest. If we find latent divergence for distance, or latent divergence of more than a metre angle at $\frac{1}{4}$ metre, or both, we can positively assert that the interni are insufficient, and we can confirm this by ascertaining the amplitude of convergence, the ordinary working distance of the patient, and the reserve power of convergence.

Except in neurasthenic insufficiency, the estimation of the adducting power of the interni by prisms is not of much use. We may get an adducting power of 30°, and yet if the externi are "preponderating" we shall have insufficiency present.

Although exophoria may be associated with uncorrected high hyperopia, due to the patient approaching his work very near the eyes in order to obtain large retinal images, it is in *myopia* that we generally find this condition, where the error is uncorrected, or only partially corrected. The excess of convergence over accommodation, and also the excessive convergence, must sooner or later cause fatigue of the internal recti.

Treatment.—In the majority of cases, when the want of muscle balance is small, the correction of the error and the *constant wearing* of the glasses will in a short time

remove the exophoria. One of the advantages of wearing the concave glasses for near work is that the work must be held some distance from the eyes, which of course means less strain to the convergence; and as this is associated with a restoration of the harmony between the accommodation and convergence, which always means less strain, one is not surprised at the good result of this treatment.

If exophoria still persists after some months of this treatment, a prism, *base in*, should be prescribed with the glasses, or, if the concave glass is fairly strong, the prism effect may be obtained by decentring the glass *out* (see Fig. 77).

When prisms are ordered, it is unwise to give the full correction. Suppose, for instance, our patient shows an exophoria with the Maddox distance test which is corrected by a 4° prism, base in, before one eye, if we give a 2° prism, base in, before each eye, we shall be helping the muscles *too much*, and give the patient no chance of improving; we should in this case prescribe a 1° *prism*, base in, before each eye.*

It should never be forgotten that the prism treatment is *not* a curative treatment; we are treating the symptom, and not helping the condition to disappear.

Even when prisms are ordered, the patient should be enjoined to use them as *special* glasses to be worn only for NEAR work.

2. **Esophoria** (*Insufficiency of the External Recti*).—When latent convergence is demonstrated for distance, we say that we have "insufficiency" of the external recti—that is, in the position of rest the externi are relatively weak. If there be no manifest convergence, the visual axes assume a parallel condition; but to maintain this, constant active contraction of the external

* The use of prisms is limited to about 4° in front of each eye, as any stronger prism would make the glasses too heavy.

recti must take place when distant vision is used, in order to prevent diplopia. Latent convergence is very common, but, in the majority of cases, gives rise to no symptoms. The explanation is, that the latent deviation is slight, and in our civilized state active use of the

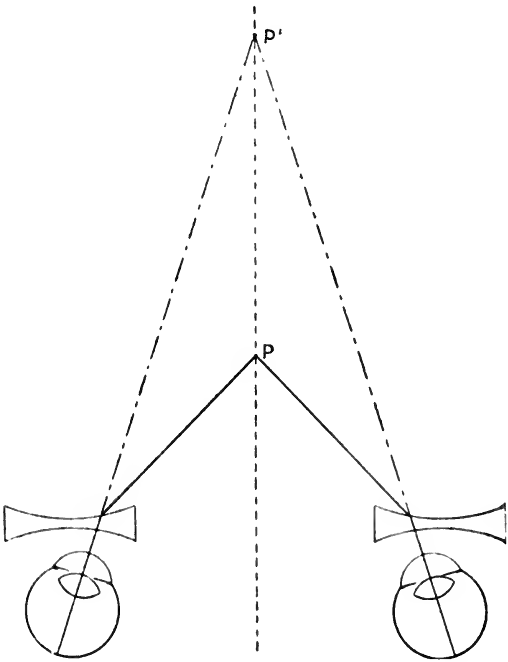


FIG. 77.

P, Object looked at; P′, apparent position.

eyes is mostly associated with a necessary convergent condition. When the latent convergence is excessive, we may get symptoms of eyestrain.

Test for Insufficiency of the Externi.—When the Maddox test reveals latent convergence for distance or for ¼ metre, it is present.

The abducting power of the normal externi is equal to a prism of 7° or 8°.

Insufficiency of the externi is generally associated with *hyperopia.*

We have seen that in hyperopia, accommodation is required in excess of convergence, and, unless the two can be dissociated, the hyperope must converge to a nearer point than is necessary. This over-contraction of the interni causes latent convergence for distance, and also for the near point (Fig. 76, D), the external recti become insufficient, and extra impulses must pass down to these muscles in order to obtain "fusion vision." This may lead to fatigue and eyestrain, which, however, often disappear, owing to the development of a convergent squint and loss of binocular vision (see page 91).

Treatment.—By putting the hyperope into glasses we re-establish the harmony between convergence and accommodation, remove the spasm of the internal recti, and consequently also the insufficiency of the externi, restoring the balance of all the muscles.

One of the pleasantest things to do in ophthalmic work is to cure a squint, or a tendency to squint, by simply giving the patient glasses. If parents would only realize that, in a large number of cases, this can be done by bringing the child early enough—*i.e.*, before the latent squint has become manifest, or possibly during the early period of the manifest squint—there would be fewer squints.

It is very seldom that we have to resort to prisms in the treatment of esophoria, but, should it be found necessary, the prism must be placed base *out,* and if decentring is substituted, convex glasses must be decentred *outwards* (see Fig. 78). (See page 208.)

NOTE.—*Method of finding the Amount of Decentring necessary to produce the Effect of a given Prism in a given Lens* (Ward Holden). —Take 8·7 mm. as the distance a lens of 1 D most be moved to produce the effect of a prism 1°, as the unit, multiply 8·7 mm.

by the number of the prism whose effect is required, and divide the product by the number of the lens in dioptres. Thus the effect of a prism 3° in a lens of 7 D is obtained by decentring that lens to the extent of $\frac{8 \cdot 7 \times 3}{7}$ mm. $= 3 \cdot 7$ mm.

3. **Hyperphoria** (*Insufficiency of the Superior or Inferior Rectus*).—This condition is revealed by the Maddox test with the glass rod vertical (see page 48).

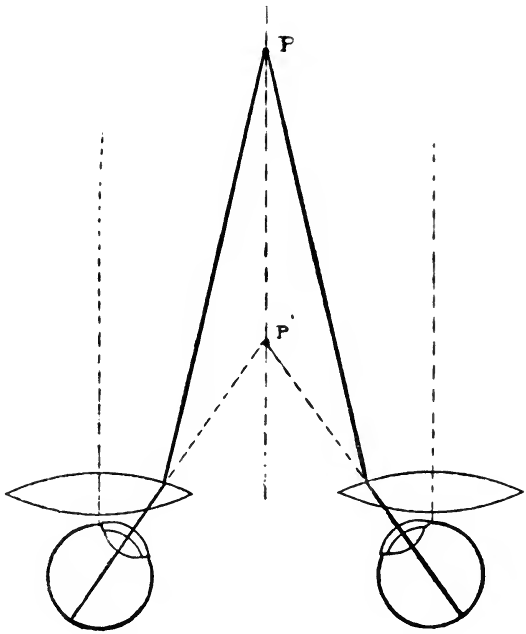


FIG. 78.

P, Object looked at; P′, apparent position.

Treatment.—A small amount is often present where an error of refraction is present, and generally disappears in a few weeks, after correction. It is generally associated with astigmatism and anisometropia.

If prisms have to be resorted to, they must be placed base up or down, according to the condition existing.

A hyperphoria is often induced when reading through glasses correcting anisometropia; for the treatment see page 158.

4. **Hyperexophoria—Hyperesophoria** (*Insufficiency of the Oblique Muscles*).—This is the result of the superior oblique of either eye being too strong for its inferior, or *vice versa*. The parallelism of the vertical meridians of the corneæ is maintained by the equilibrium of these muscles; hence, when one muscle is weaker, excessive work must be put upon it in order to preserve the parallelism, and eyestrain results.

The Maddox rod test reveals the heterophoria.

We must hope that the correction of the refractive error will remove the want of balance, and, if necessary, we must use prisms set obliquely; but some cases, unfortunately, appear to be incurable.

5. **Cyclophoria.**—This is a rare form of heterophoria, and is due to the turning of one or both eyes round an antero-posterior axis. If the Maddox rods in a frame are placed exactly horizontal before one eye, and the streak of light is seen by the patient as being more or less sloping, instead of perfectly vertical, cyclophoria is present. When present, it is generally found associated with oblique astigmatism. (See Maddox, "Ocular Muscles," 1907, page 236.)

Treatment.—Extreme care should be taken to correct completely the errors of refraction, and very special care should be taken in ascertaining the exact angle for the cylinder, and also in ascertaining that the optician has rigidly carried out instructions. As a rule, this suffices to remove the trouble. Prisms are of no use.

Heterophoria in Emmetropia.—Although rare, this condition may exist, and may be due to—

1. Excessive or prolonged convergence.

This generally produces at first an esophoria, probably

due to slight spasm of the internal recti, and later, when fatigue sets in, an exophoria. It is difficult to say whether this form of heterophoria produces any definite symptoms, as the eyestrain that may be present is more likely due to the strain of the accommodation.

2. Weakness of certain muscles produces "inefficiency," caused by general debility, especially noticed in those recovering from a severe illness.

3. Congenital defect. One of the external muscles may be attached to the eyeball too far forward, or its opponent too far back.

Treatment.—In the healthy, *rest* of the eyes is the obvious treatment, if symptoms of eyestrain appear; and if an excessive amount of fine near work (such as miniature painting) has to be done, short periods of work should alternate with outdoor exercise and some other form of rest to the eyes.

When the heterophoria is the result of defective or enfeebled muscles, we must first of all improve the general health by enjoining outdoor exercise and attention to the bowels, and by the administration of tonics, and then, remembering that absolute rest will only tend to increase the weakness, we must commence regular exercise of convergence (if we are dealing with "convergence insufficiency") for short periods, gradually increased, and forbid the patient to use the eyes for near work except at these times. To carry out this treatment in young subjects the use of a cycloplegic is most helpful. Forced or prolonged efforts of convergence would only help to increase the fatigue of the internal recti, and therefore we must commence with very short efforts, and increase those efforts very slowly.

Orthoptic training or gymnastic exercises can be, with very great benefit, extended to the extrinsic muscles. For strengthening the internal recti we employ properly regulated convergence for a short time at different periods of the day, the time to be gradually increased

as the muscles increase in strength, measured, of course, by the tests previously cited. For strengthening the external recti we must employ prisms with their base in. The best plan is to provide the patient with a square prism—say 2°—and tell him to practise fusion several times a day; and when this is accomplished with ease, we can gradually increase the strength of the prism until the "insufficiency" disappears.

As a last resource, weak prisms, with their base in, may be ordered for convergence insufficiency. With their help the convergence effort is diminished, but all hope of the muscles regaining their normal condition must be abandoned, unless the prisms are only used temporarily while the general condition is being improved. Prisms employed in this way never *cure* "insufficiency"; they only *relieve* it.

Treatment by Tenotomy.—In a few special cases tenotomy has succeeded when the milder treatment has failed. The cases where it is likely to be beneficial are patients with marked exophoria possessing an ample range of convergence. A tenotomy of one or both external recti, and in bad cases advancement of an internal rectus, will remove the exophoria; and by this setting free the whole of the convergence power, by turning the "negative" convergence into "positive," the symptoms of eyestrain are removed.

Landolt gives a very good example of such a case (Fig. 79, *a*). Before the operation there was 3 m.a. of divergence, and the convergence near point was 14 cms. with eyestrain. In this case

$$\text{ca} = \tfrac{100}{14} - (-3) = \tfrac{100}{14} + 3 = 10 \text{ m.a.},$$

but only seven of these 10-metre angles of convergence power were available; tenotomy of the external rectus removed the divergence, the whole of the 10 m.a. became available, and the eyestrain disappeared (Fig. 79, *a′*).

Fig. 79, *b*, illustrates another case which was cured

by tenotomy; here the result was not so perfect as in the first case (Fig. 79, *a*).

Fig. 79, *c*, is an example of what Landolt calls *neuras-*

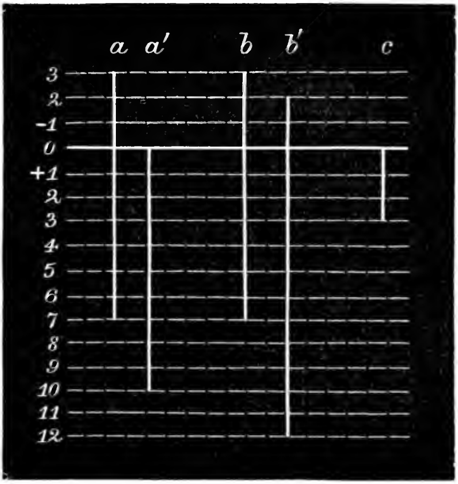


FIG. 79.

thenic insufficiency, when the amplitude of convergence is exceedingly small, and when tenotomy can do no good.

Malingering.—A malingerer will sometimes pretend that one eye is blind, in order to escape war service, or to obtain compensation after injury. Malingering is sometimes a symptom of hysteria. It may be detected by—

1. *The Prism Test.*—Both eyes being uncovered, and directed to a distant object, a prism, base up or down, is placed before the "blind" eye. Diplopia is complained of if the eye is not blind, and the fraud is exposed.

If a 6° prism is held before the "blind" eye, base out, this eye will move in, at the moment of placing the prism, in order to avoid diplopia, if it is *not* blind.

2. *The "Friend" Test* (see page 153).—The malingerer does not know that with this test he can read only half the letters with one eye. If he reads the whole word, he is detected.

3. *Bishop Harman's Diaphragm Test.*—This instrument is not only useful for detecting malingering, but is also a very ready test of binocular vision and its defects. (For description, see *The Ophthalmoscope*, vol. viii., p. 495.)

CHAPTER XIV

STRABISMUS

Squint.—A heterophoria, or latent squint, may at any time become heterotropia, or manifest squint, if the necessary muscular effort to preserve parallelism cannot be made or maintained. Thus, insufficiency of the internal recti in myopia, produced by excessive convergence, may become temporarily or permanently a divergent squint, and we have already seen how a convergent squint develops when the patient cannot use his accommodation in excess of his convergence in hyperopia (page 91).

Varieties of Squint.—(1) *Concomitant*, in which the squinting eye moves with its fellow, and always deviates to the same degree from the correct position.

(2) *Paralytic*, when the movement of the squinting eye is restricted by paralysis of the muscle.

We shall deal in these pages only with the first variety.

Forms of Concomitant Squint—(1) *Convergent.*—Internal squint (esotropia).

If the squinting eye is not amblyopic, there is homonymous diplopia. In Fig. 80, R, the right eye is fixing the object O, but L, the left eye, which is squinting in, receives the image of O at M′, which is on the nasal side of the macula M; hence the left eye projects O to the left or *same* side.

2. *Divergent* strabismus.—External squint (exotropia).

If the squinting eye is not amblyopic, there is heteronymous or crossed diplopia. In Fig. 81, R, the right eye, is

fixing the object O, but L, the left eye, is squinting out, and receives the image of O at M′, which is on the temporal side of the macula M; hence L projects O to the right or *opposite* side.

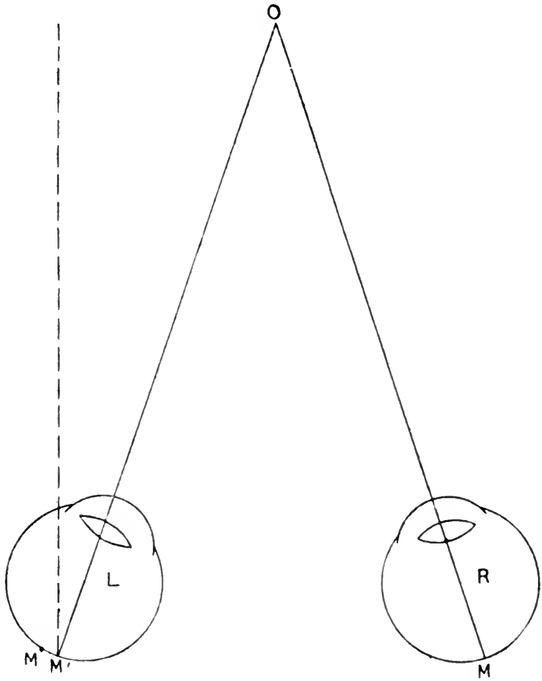


FIG. 80.—HOMONYMOUS DIPLOPIA.

3. *Vertical* strabismus (hypertropia), in which the visual axis of one eye is deviated upwards.

These three different forms of concomitant squint may be—

1. *Constant*, in which one eye is always the squinting eye. This condition is also called *monolateral*.

2. *Alternating*, in which either eye can fix, the fellow

squinting; in these cases the vision of both eyes is generally equally good.

Squints may also be *periodic* or *intermittent*. When the squint is developing—for instance, when the heterophoria is passing into a heterotropia—the latter may be

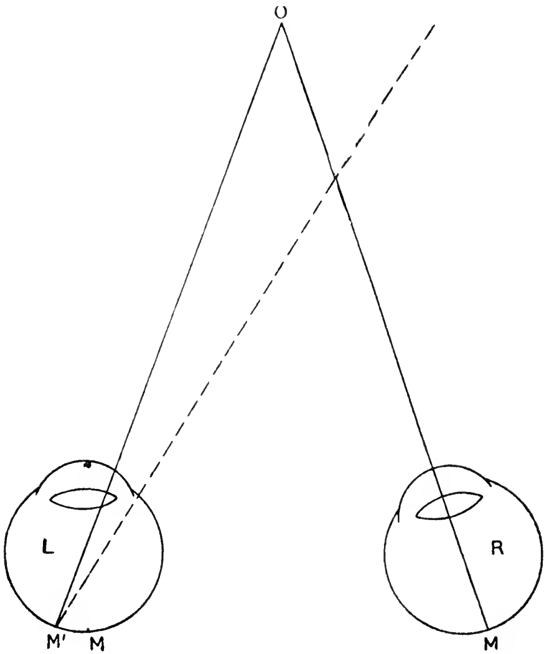


FIG. 81.—HETERONYMOUS DIPLOPIA.

manifested only after fatigue, or when certain constitutional conditions are present.

Maddox puts the case very clearly, thus: When the breadth of diplopia is greater than the breadth of fusion power, no effort can unite the images, and this is (1) a constant squint. When they are almost equal, the images may be united by a great effort for a short time;

this is (2) a periodic squint. When the breadth of diplopia is considerably less than the breadth of fusion power, the images are easily united, and this is (3) a latent squint (heterophoria). The difference between the three is merely a question of degree.

Angle Gamma.—We must be careful to distinguish between a real squint and an apparent squint. We may have in hyperopia an apparent divergent squint, and in myopia an apparent convergent squint, due to the visual and optic axes not coinciding.

When the optic axis passes through the fovea it coincides with the line of vision or line of sight, and also with the line of fixation; but the exception to this is the rule, and an angle is formed by the line of fixation M O with the axis A A′ (Fig. 82). This angle is called the angle gamma (O M A). (The angle O K A [Fig. 82] made by the *line of vision* and the optic axis may be considered identical with the angle O M A, and is sometimes called the angle gamma.)

The angle gamma is *positive*, as in Fig. 82, when the fovea is on the outer side of the optic axis, and it is generally positive in emmetropia and hyperopia, and in some cases of hyperopia the angle is so great (amounting even to 10°) that it gives the eyes an appearance of divergence (see Fig. 83)—an apparent divergent squint; the eyes, although looking at and fixing the point O, appear divergent in the direction A O′.

The angle gamma is *negative* when the fovea (F, Fig. 84) is on the inner side of the optic axis—that is, between the optic axis and the optic nerve. In some cases of myopia this is so marked as to give the eyes the appearance of convergence (see Fig. 84)—an *apparent convergent squint;* the eyes, although looking at the point O, appear to converge in the direction of A O′.

The angle alpha (O X E, Fig. 82) is the angle formed by the axis which passes through the most curved part of the cornea (the summit) with the line of vision. It is spoken of as positive when, as in Fig. 82, the anterior portion of the corneal axis is situated on the outer side of the line of vision, and negative when it is on the inner side. Generally the axis of the cornea very nearly coincides with the optic axis, so that for all practical purposes the angles gamma and alpha mean the same thing.

The Ætiology of Concomitant Squint.—Any cause which disturbs the muscular equilibrium may be the starting-point of a squint, so that any of the causes of heterophoria (see page 174) may be the factors in the causation of a squint; but the chief are—

1. *The Accommodation Theory.*—We have already seen how, in hyperopia (page 91), when the patient has

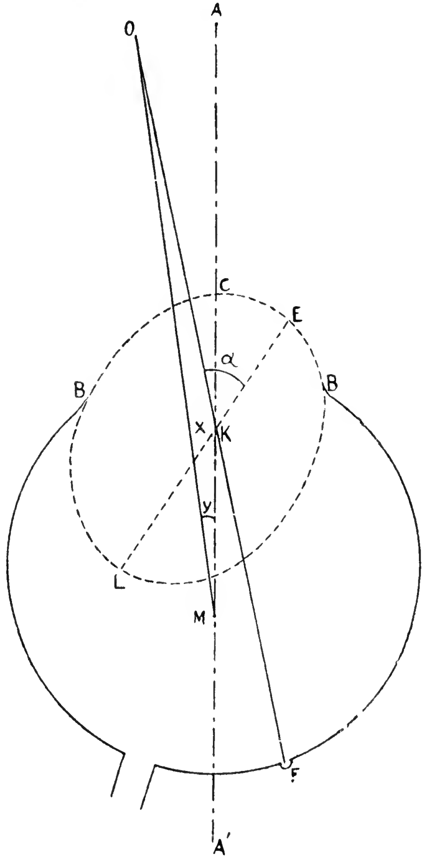


FIG. 82.—A SCHEMATIC FIGURE TO SHOW ANGLES α AND γ. (AFTER LANDOLT.)

A A′, Optic axis; K, nodal point; M, centre of rotation; C, centre of cornea; B B, base of cornea; E L, corneal axis; F, fovea centralis; O, point of fixation; K O, line of vision; M O, line of fixation; O X E, angle α; O M A, angle γ.

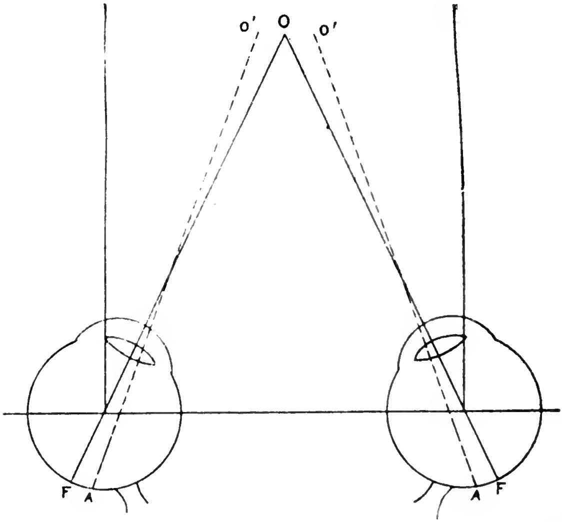


FIG. 83.—APPARENT DIVERGENT STRABISMUS DUE TO A LARGE POSITIVE ANGLE GAMMA.

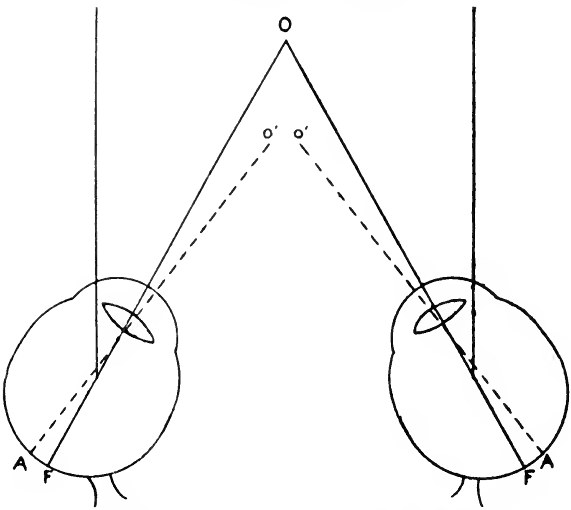


FIG. 84.—APPARENT CONVERGENT STRABISMUS DUE TO A NEGATIVE ANGLE GAMMA.

to use his accommodation in excess of his convergence, a convergent squint is developed, if he cannot dissociate the two; he has to choose between indistinct binocular vision and clear monocular vision with a squint, and he chooses the latter.

Again, in myopia he has to use his convergence in excess of his accommodation; "insufficiency" of the interni develops, and in time an external squint is manifest.

2. *Anatomical Peculiarities—The Muscle Theory.*—A broad face with a large interpupillary distance means the necessity for greater convergence; a narrow orbit with a long myopic eye prevents freedom of movement of the eye, and consequently causes greater strain and the necessity for greater muscular effort in convergence. The external rectus may be inserted into the eye too far forward or the internal rectus too far back, or *vice versa*.

Any of these conditions, especially if associated with ametropia, may be strong factors in the causation of a squint.

3. *Non-Development of the Fusion Sense.*—At birth the eyes move independently of each other, and hence new-born children often squint. As they begin to take notice of surrounding objects they develop the power of fusion, and the two images which fall on the maculæ are thus fused by the brain, the centre being known as the "fusion centre," or centre for binocular vision.

Any cause which reduces the visual acuity of one eye tends to develop a squint, especially if a heterophoria or latent disturbance of equilibrium pre-exist. Among the commonest causes may be mentioned corneal opacities, cataract, and intra-ocular diseases. Thus, a patient with heterophoria has an attack of keratitis in one eye; corneal opacities result, which lower the visual acuity of this eye, and a manifest squint develops.

The amblyopia may be congenital.

NOTE.—This amblyopia, which causes, or helps to cause, a squint, must not be confused with the amblyopia which is the *result* of the squint, and which develops through the non-use of the eye. When a squint develops, diplopia must occur at first, and to get rid of

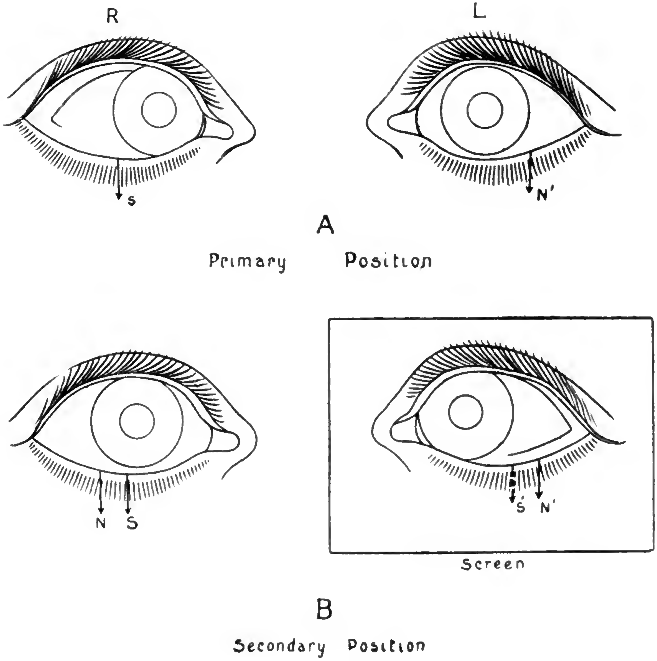


FIG. 85.

this diplopia, the brain refuses to recognize the image from the squinting eye; this form is called *amblyopia ex anopsia*.

Worth maintains that the *essential cause of squint* is a defect of the fusion faculty, and that this defect alone is sufficient, even if there be *no* error of refraction.

The Diagnosis and Measurement of Concomitant Squint.—Let us proceed to measure a convergent squint.

Make the patient fix an object, say, a couple of metres from the eyes, taking care to place the object midway between the two eyes. Let us suppose that the left eye fixes the object and the right eye squints inwards: we note the external margin of the cornea of both eyes by making a small ink spot on the lower lid; let *s* be this mark on the right eye (Fig. 85) and N′ on the left. We now cover the left eye with a screen, and tell the patient to fix the object again; this he does with the right eye, and we notice a marked excursion of this eye; we now note the position of the external margin of the cornea N. The distance N S is the **primary deviation.**

When the left eye is covered and the patient is fixing with the right eye, if we look behind the screen we notice that the left eye makes a distinct incursion; and if we mark on the lid the two positions of this eye, we get the distance S′ N′ as representing the **secondary deviation,** which is equal to the primary deviation. This enables us to diagnose very easily between a concomitant and a paralytic squint, for in the latter the secondary deviation is always very much greater than the primary. We measure a divergent squint in the same manner.

When the squinting eye is blind, we must use a strabismometer (Fig. 86), and read off on the scale the amount of the squint in millimetres.

A much more reliable method is to measure the amount of squint by the perimeter (Fig. 87). Placing the patient so that the squinting eye is opposite the fixation-point F, and with both eyes uncovered, we direct him to look at a distant point D, the squinting eye and F and D being all in one line. We now hold a small candle or match at the fixation-point F, and gradually move it along the arc, which is placed horizontally, looking directly behind the candle for its image reflected on the cornea of the squinting eye.

When the image is in the centre of the pupil we read off the position of the candle on the arc, and the degree mark represents the angle of the strabismus.

Treatment.—

1. The correction of the error of refraction.
2. The education of the fusion sense.
3. The education of the amblyopic eye.
4. The readjustment of the muscles by operation.

Convergent Strabismus.—Almost 80 per cent. of patients suffering from convergent strabismus are hyper-

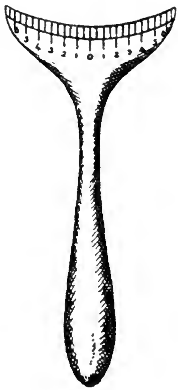


FIG. 86.

opes, and the defect is manifested very early in life—in fact, when the child begins to use his eyes for near vision, looking at picture-books, etc.; the majority of such patients develop a squint *about the age of three.*

The squint, as a rule, develops slowly, and the parents are not the first to notice it. They generally assign as the cause an illness, such as measles, or the imitation of a squinting companion.

The first treatment is to put the eyes under atropine for at least a week, and in slight cases the squint entirely

disappears when the eyes are fully under a cycloplegic. The refraction is then estimated by retinoscopy, and the

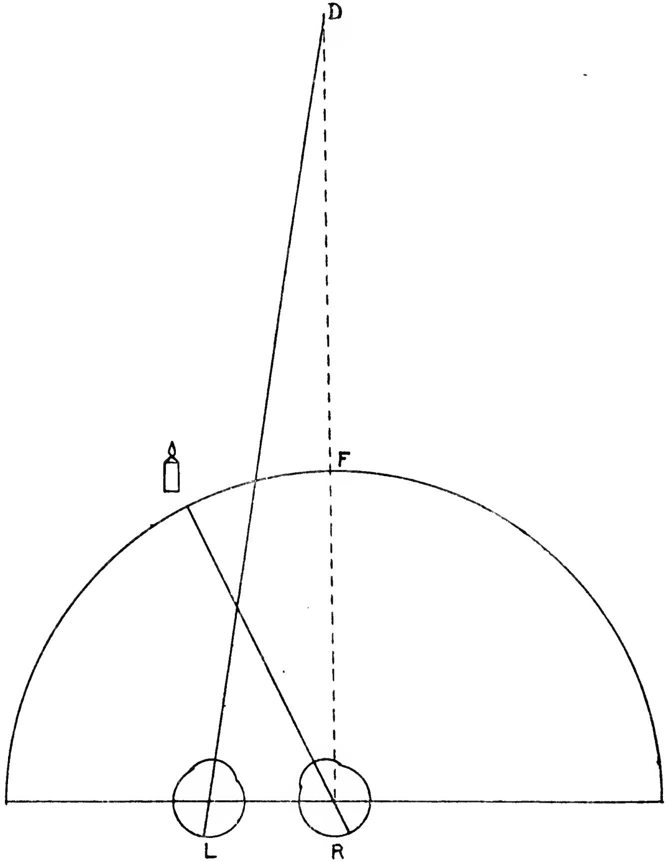


FIG. 87.

full correction, less 1 D, is ordered in large oval or circular spectacles, to be worn always. For instance, suppose under atropine retinoscopy at 1 metre gives

+4, then the full correction is +3, and the glasses iven would be +2. With an intelligent quiet child spectacles may be ordered at three years of age, with instructions, of course, for their removal when the child is romping.

If the atropine removes the squint, as a rule the glasses will also do so.

Be careful to insist upon the *constant* use of the glasses, and inform the parents that this treatment will probably have to be persevered in for years.

If the squinting eye is amblyopic, the child should be made to practise it by placing an opaque clip on the glass of the good eye, or, what is better still, especially with the very young, by bandaging up the good eye and forcing the bad eye to be used for a short time every day—for instance, at mealtime. In many cases this treatment results in great improvement of vision (see page 96).

Another useful method of forcing the amblyopic eye to work, is to instil atropine into the good, or fixing, eye only; as the accommodation of this eye is paralyzed, it can only be used for distant vision, and for near vision the amblyopic eye must be used, and is then forced to work for a considerable period of the day. Some surgeons consider that this treatment takes the place of, and is better than, excluding the fixing eye with a bandage.

The use of atropine in *both* eyes (except for the purpose of estimating the error of refraction), which is sometimes advocated when the child is considered to be too young for glasses, is to be strongly condemned.

As an essential cause of convergent squint may be a defective development of the fusion faculty, the orthoptic training is very important, and cannot be begun too early.

Worth has devised an instrument called the *amblyoscope*, which is on the principle of the stereoscope: each eye looks through a separate tube, and a different part

of the whole picture is placed before each tube, and so arranged that when both eyes are being used these two portions are fused into one picture. These tubes are not fixed together, but can be separated to any angle, and thus adjusted to the particular squint (see *Trans. Ophth. Soc.*, vol. xxi., page 245). The picture before each tube can be separately illuminated, and so, by lowering the illumination of the picture before the better eye, or increasing that before the worse eye, binocular fusion vision may be easily obtained in very bad cases, and consequently Worth's amblyoscope is far superior to the numerous cheaper stereoscopic instruments.*

The above treatment should be given a good trial as long as the smallest improvement is shown; but when no improvement is taking place, and especially when the squinting eye is becoming amblyopic or more amblyopic, we must resort to operation.

Squint operations are always best done under cocaine and adrenalin, because, when the patient is conscious, we are able to judge accurately the amount of adjustment necessary; but when we have to operate on quite young children, a general anæsthetic is necessary.

In slight convergent strabismus, division of the internal rectus may be sufficient; if not, we must advance the external rectus of the same eye; and lastly, in rare cases, division of the other internal rectus may be necessary.

The younger the patient, the more likely is the treatment of atropine (in the fixing eye) and glasses to succeed and the operation to be unnecessary; but in older subjects, squints are rarely cured except by tenotomy or advancement, or both.

While the spectacle treatment is being tried, the

* Worth considers that the training of the fusion sense cannot be begun too early, and that it is rarely of any use after the age of 6. The surgeon should himself give the child the "lesson" with the amblyoscope once a week for at least six weeks.

refraction should be carefully estimated under atropine at least once a year.

Divergent Strabismus.—This condition is rarely seen in young children, and, as a rule, develops at puberty or later—in fact, when myopia is progressing. By stopping undue convergence, and so helping to restore the fatigued internal recti, we may cure slight cases at the onset by putting the patient into glasses; but it is very uncertain, and in the majority of cases, when once the "insufficiency" has passed into a squint, nothing short of an operation is any good. This consists in dividing the external rectus, and, when this is not sufficient, in advancing the internal rectus. Training the eye, and so trying to reduce the amblyopia, should also be resorted to. When the squint is not very marked, give the glasses and the orthoptic training a fair trial of, say, six months before resorting to operation.

After squint operations it is most important for the patient to continue to wear the correction, and also to persevere with the stereoscopic training. He should be warned that, unless this is done, there is a danger of further trouble—for instance, a convergent strabismus that has been corrected may develop into a divergent strabismus, etc.

In oldish patients with an old convergent squint, where the squinting eye is not amblyopic, and when an operation is refused or deemed inadvisable, if diplopia is present, prisms base out must be ordered with the correction.

CHAPTER XV

CYCLOPLEGIA, CYCLOPLEGICS, AND CILIARY SPASM

Cycloplegia.—Cycloplegia, or paralysis of the ciliary muscle, may be due to—

1. Drugs, such as atropine.
2. Systemic poisons — diphtheria, influenza, syphilis, etc.
3. Disease of the nervous system, concussion of the brain, etc.

Cycloplegics.—A cycloplegic is a drug which temporarily paralyzes the ciliary muscle, and by its use we are enabled to estimate the refraction of the eye at rest. Cycloplegics are also mydriatics—that is, they paralyze temporarily the sphincter iridis, and cause dilatation of the pupil.

The only cycloplegics we need concern ourselves with in refraction work are *atropine* and its derivative, *homatropine.* These drugs paralyze the sphincter iridis and the oculo-motor nerve-endings in the ciliary muscle; consequently the pupil is dilated and accommodation power is reduced, or (when the full action of the drug is obtained) lost, leaving the eye adjusted for its far point and in a state of rest.

Atropine is the stronger drug, and should be used, when practicable, in all young subjects where the amplitude of accommodation is very great. In children under 16 years the full effect is obtained only after two days' use; in older patients complete cycloplegia may occur in a few hours.

The effect of the drug does not begin to pass off for thirty-six hours, and the accommodation power is not fully restored until a week or ten days have elapsed. The pupil is restored to its normal size about the same time, sometimes a little earlier.

Homatropine has the same general effect as atropine, but differs in that its full effect on the pupil and ciliary muscle manifests itself more promptly, and disappears much more rapidly, than atropine; but it is not so complete a paralyzer of the ciliary muscle as atropine, and in young people whose accommodation is very active it is not to be relied on. On the other hand, in most people over 25 years of age it paralyzes the muscles quite enough for all practical purposes when used in sufficiently strong doses and combined with cocaine.

Cocaine favours the absorption of the drug by rendering the outer epithelial layer of the cornea and the conjunctiva more pervious.

As a general rule, the full effect of homatropine is obtained in an hour. This effect begins to pass off in two hours, and the whole effect has disappeared in twenty-four or twenty-six hours. The restoration of the pupil to its normal size takes a few hours longer.

Between the ages of 16 and 20 the selection of the cycloplegic must depend on the time that the patient can give up to the examination. Always try and obtain consent for the use of *atropine* in such cases, as its effect is more reliable; but where only one day can be spared, the surgeon will have to be content with homatropine. In young subjects at school who cannot give up the time to atropine cycloplegia, homatropine should be exhibited two or three times at intervals of half an hour before the refraction is estimated; but if a satisfactory result is not obtained, atropine will have to be used. One great advantage of homatropine is that it rarely, if ever, produces toxic symptoms.

The Form in which Cycloplegics should be used.—It

is impossible to know when using drops or solutions how much of the drug is absorbed and how much is wasted, and they do not keep well. Atropine in solution is liable to produce toxic symptoms by passing down the tear passages into the throat.

On the other hand, ophthalmic " tabloids " and discs have been brought to such a state of perfection that they form the most scientific, efficient, and safe method of administering the drugs.

The most useful tabloids are: atropine $\frac{1}{200}$ gr., and homatropine with cocaine $\frac{1}{50}$ gr. each.*

Tabloids or discs should dissolve quickly when placed on the inner surface of the lower lid, and should cause little or no irritation or pain.

Atropine may also be used in the form of an ointment, the pure alkaloid being dissolved in vaseline, the proportion being gr. iv. of atropine to the ounce of vaseline. This should be put up in a small tube, and a small quantity placed on the inside of the lower lid, by means of a clean glass rod, morning and late afternoon. It should not be used on the day the examination is to be made, as the presence of the vaseline may interfere with the tests.

Cycloplegics are rarely necessary over the age of 45. The accommodative power is considerably reduced by that time, and any latent hyperopia that may have been present has become manifest (see Presbyopia, page 149).

Never use a cycloplegic should there be any suspicion of glaucoma or a tendency to glaucoma.

Make it a rule never to use *atropine* in patients with high hyperopia over 25 years of age, and then there need be little fear of inducing a glaucomatous attack, because *homatropine* is very speedily and efficiently counteracted by eserine, and if homatropine has been used, and any suspicious symptoms arise, a tabloid of eserine ($\frac{1}{600}$ gr.) will allay all anxiety.

* Burroughs, Wellcome and Co., tabloids " B " and " W."

Cycloplegia following Diphtheria.—When the accommodation is paralyzed after diphtheria, it generally occurs in young subjects, is bilateral, and may follow a most insignificant attack of the disease. The patient is in the same condition as an old person who has lost all accommodation, and the treatment is practically the same. If emmetropic, reading glasses only are necessary, and the weakest convex glasses with which reading is possible should be prescribed in order to encourage the ciliary muscle to act, and these glasses should be changed for still weaker ones as the power returns to the muscle. When an error of refraction is present, bi-focal glasses for distance and near vision must be ordered (see Presbyopia, page 150).

As dilated pupils from iridoplegia very often coexist with cycloplegia, considerable improvement in vision may result from the use of a drop of eserine in the eyes every morning.

When cycloplegia results from any other cause, the aforesaid treatment should be adopted, combined with the internal administration of iodide of potassium or strychnine, etc., as may be indicated.

Spasm or Cramp of the Ciliary Muscle.—This is the opposite of cycloplegia, and occurs in two forms: (1) A temporary spasm, soon passing off with rest; (2) a permanent spasm, referred to in the previous pages as *spasm of accommodation*, and generally associated with hyperopia in young people (see page 94), and producing an apparent myopia. Both forms are the result of strain of the ciliary muscle, and are, with rare exceptions, cured by the use of a cycloplegic and the correction of the refraction error.

There is a form of spasm of the accommodation which Leslie Paton calls "functional spasm." In the case he cites (*Trans. Ophth. Soc.*, vol. xxxvii., p. 370) a lady with a small amount of myopic astigmatism at times acquired a spasm of accommodation of 9 or 10 D, accompanied by "cramp of convergence." This condition is seen in neurasthenic patients and is produced by eyestrain. De Schweinitz ("Diseases of the Eye," 8th edition, p. 122) says: "Spasm is prone to occur in individuals of neurasthenic condition, and is a frequent symptom of hysteria, often associated with cramp of convergence."

This form of spasm may occur in quite old patients, even up to 45. Most meticulous care should be employed in ascertaining the refractive error, and the proper correction will in time effect a cure.

All these forms of spasm are exaggerations of the tonic spasm that exists in normal conditions and which disappears under the action of a cycloplegic.

CHAPTER XVI

METHODS OF EXAMINATION—NOTE-TAKING

Methods of Examination.—The **room** should, if possible, be sufficiently long to allow the patient to be seated 6 metres, or 20 feet, from the type. When this length is not obtainable (even diagonally), reversed types must be used and hung over the patient's head behind him, and opposite should be a mirror, on which the type is reflected. The distance should be so arranged that the distance between the patient and the mirror and between the mirror and the type together measure 6 metres.

Apparatus Required.—The **distant type** should be Snellen's type, and several boards, with a different arrangement of letters, should be used, and changed as necessity arises, or they may be arranged in a box form and rotated by a cord by the surgeon from where he is standing. Dixey's test types* (Fig. 88) are arranged so that only *one* line of type is displayed at a time, the different lines being turned into position as required by a cord, as in the box form of type. The change of type prevents the patient from learning the arrangement of the letters.

The type must be well and evenly illuminated, preferably by artificial light, and, if possible, in a dark part of the room, so that the difference between a bright and dark day has little or no effect on the record.

* Dixey, 3, New Bond Street, W.

A dark room, although desirable, is not absolutely necessary; the whole consulting-room can be darkened with a blind or curtain, or a dark corner can be curtained off. *Absolute* darkness is not a *sine qua non.*

The lighting should, if possible, be electric, and ground-glass lamps should be used, or the special high candle-power lamp made for eye or throat work, which is mostly ground glass with a small portion clear. Failing the electric light, the "incandescent" is, perhaps, the best form of gas illumination.

FIG. 88.

The **reading type** should be kept clean in a cover. Both forms of type are figured at the end of the book.

The Trial Case.—This contains pairs of concave and convex spherical and cylindrical lenses and prisms. The spherical lenses should be numbered in intervals of ·12 to 1, ·25 to 4, ·5 from 4 to 8, and in interva's of 1 from 8 to 20.

The cylindrical lenses should be numbered in intervals of ·12 to 1, ·25 from 1 to 3, ·5 from 3 to 6, and intervals of 1 from 6 to 8.

The prisms should be from 1° to 12°, or 14°.

The lenses should be as thin as possible, and they should all be mounted in thin frames, with a small flat handle on which the number is engraved.

When the surgeon does not wish to start with so expensive a set of lenses, he can manage very well with a set consisting of the following glasses:

- Sphericals, convex and concave: 30 pairs each from ·12 to 20.
- Cylindricals, convex and concave: 18 pairs each from ·12 to 6.
- Prisms from 1° to 12°.

This set in a suitable case with stenopaic discs, adjustable trial frame, etc., can be supplied by Messrs. Hamblin, 5, Wigmore Street, at a reasonable cost.

Trial Frame.—Get a really good trial frame, regardless of cost. One of the best is made by Curry and Paxton. It should be light (made of aluminium), capable of being adjusted to fit any patient, and of being correctly centred. It should have a screw for rotating the cylinder (which can, if necessary, be used by the patient), for by this means we insure much greater accuracy in obtaining the correct angle of the cylinder. It should be so arranged that where two lenses are used—*i.e.*, a sphere and a cylinder—they should almost touch, and the back glass should be as close to the eye as the lashes will permit. There are many bad trial frames on the market, the worst example being the rigid one supplied in most trial cases, which is practically useless.

Besides the above contents of the trial case, there should be several " blanks " to block off vision, a stenopaic slit, a pin-hole disc, and neutral tinted glasses of various shades.

Refraction Ophthalmoscope.—It is false economy to buy a cheap one. Get a good instrument to start with, and it will last a lifetime (see page 61).

Ophthalmoscopic Mirrors.—A plane and a concave mirror are wanted, and these may be procured in one, each mirror serving as the cover of the other (see page 83).

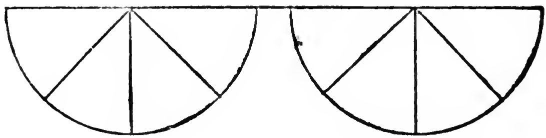
Focus-glass.—A large focus-glass, as described on page 62.

Maddox Apparatus.—The test-board, near test-type, rod and prism (see page 45).

Perimeter.—McHardy's recording perimeter is the best, but is expensive; there are many almost as useful, and much cheaper.

The *Ophthalmometer* is an expensive instrument, but is really indispensable (see page 126).

Cycloplegics.—Tabloids of homatropine and cocaine, āā gr. $\frac{1}{50}$; atropine, gr. $\frac{1}{200}$; and eserine, gr. $\frac{1}{600}$.



R L.

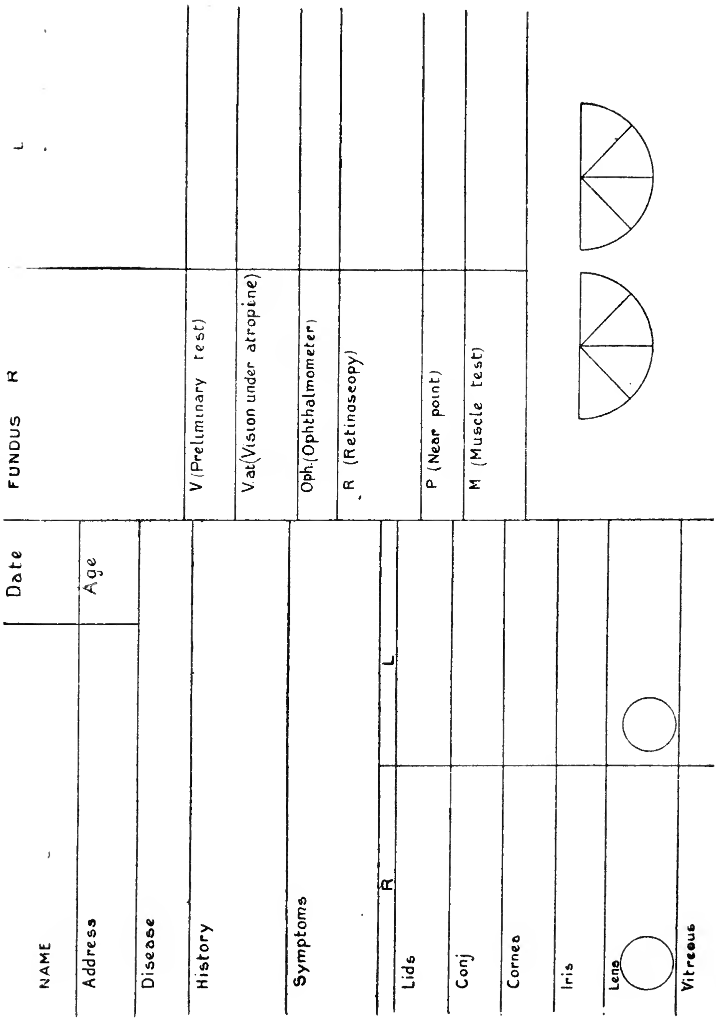
FIG. 89.

Prescription forms for spectacles are supplied by most opticians, or they can be engraved or stamped on the surgeon's own paper, as illustrated in Fig. 89.

Mark the axis by writing the degree as indicated at page 138.

Note-Making.—It is very useful in recording notes of patients to have some scheme. Fig. 90 is a suggested form when using the card system, but if the surgeon wishes more voluminous notes, and especially if he prefers a bound book, the ophthalmic case-book, published by Pulman, of Thayer Street, W., will meet all his wants.

The Systematic Examination of the Patient.—After recording name, age, history, and symptoms, the patient is placed in the chair opposite the type, and the trial


NAME
Date
Address
Age
Disease
History
Symptoms
R
L
Lids
Conj
Cornea
Iris
Lens
Vitreous
FUNDUS R
L
V (Preliminary test)
V. at (Vision under atropine)
Oph. (Ophthalmometer)
R (Retinoscopy)
P (Near point)
M (Muscle test)

frame is adjusted. With one eye blocked, the visual acuity of each eye is separately recorded, and also roughly the effect of concave or convex glasses. There is no necessity to waste much time over the first examination if a cycloplegic is going to be used. On the patient's return under atropine or homatropine, take him straight into the dark room, examine carefully with the ophthalmoscope, and then ascertain the refraction by retinoscopy. If you have an ophthalmometer, measure the astigmatism. Then take the patient back to the type examination, find out the glass or combination of glasses that give best vision, record this, and let him return for a final visit when the effect of the cycloplegic has passed off, when you order the correction. When the patient cannot return for a third visit, you must order the glasses according to the rules laid down in the previous chapters.

Of course, when a cycloplegic is not used, the examination is completed in one visit.

Remember that in old patients hyperopia is often present and absolute, and a weak convex glass will often improve vision from $\frac{6}{60}$ to $\frac{6}{6}$.

Always note and record the spectacles that have been previously worn.

CHAPTER XVII

SPECTACLES

Spectacles.—The treatment of errors of refraction cannot be considered to be complete unless the optician has accurately made up the prescription, consequently it is very important for the surgeon to check the glasses and their fit; if practicable, this should never be omitted. The optical centre of the glass should coincide with the visual axis. Distance glasses should be centred for distance, and near-work glasses for the point at which they are intended to be used. Glasses for constant use should be centred for a point between these two.

Glasses have a prismatic effect if decentred. A convex glass may be said to consist of two prisms with the bases in contact. If the glasses are too wide apart, the patient looks through the inner side of the glass, which has the same effect as looking through a prism with its base outwards (see Fig. 78); consequently the convergence effort will have to be increased. If the glasses are too close together, we have the same effect as a prism with its base inwards, and the convergence effort will be diminished, the accommodation being in excess. Concave glasses may be said to be two prisms with their apices in contact, and the effect of their being out of the centre is the reverse of that of convex lenses (see Fig. 77). When these results are not desired—that is, when the lenses are not purposely decentred—it is easy to understand how badly-fitting spectacles may be worse than useless.

To check the centring of the glasses, draw a thick vertical ink line on a piece of paper, hold the lens at a slight distance from it, and move it from side to side; when the lens is convex, the line seen through the lens will appear to move in the *opposite* direction; when concave, in the *same* direction. In Fig. 91 a convex glass has been moved to the right, and the line seen through the lens has moved to the left. By moving the lens from side to side the neutral part will be found where the lines are continuous; this is the optical centre for lateral movement. Mark this point as a short vertical line on

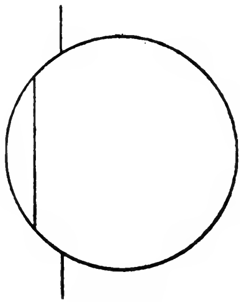


FIG. 91.

the lens with ink or a special grease pencil; now turn the lens round through 90° and proceed as before; where the two lines meet is the optical centre of the lens, and this should correspond with the centre of the pupil when the eyes are adjusted for the distance for which the glasses are ordered.

If a prismatic effect is desired and ordered, then the optical centre should be decentred as explained on page 178.

The plane of the glasses should be perpendicular to the visual axis when in use, hence reading glasses should be tilted forwards.

The best form of **bridge** is the saddle-bridge; it should be flat in order not to indent the nose, and should fit the

nose accurately. It is not unusual to find that the lower elbows (Fig. 92, *b*) are touching the sides of the nose, but that the upper arch (Fig. 92, *a*) is not in contact. If the bridge is not well made, the spectacles will slip.

Sometimes, however carefully the bridge is adjusted, it indents the nose in young children, and perhaps tends to interfere with the development of the nose; Hamblin's "scholar's frame" remedies this, as the bridge is lifted off the nose by side clips, the glasses having the appearance of a combined spectacle and pince-nez.

The glasses should be as near the eyes as the lashes will permit; 13 to 14 mm. is the average distance; but when the lashes are very long, this distance will have to be increased. It is most important to remember that

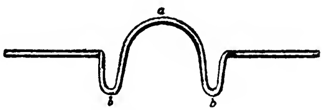


FIG. 92.

the lashes must not touch the glass; when the lashes are very long, periscopic lenses should be ordered.

Concave glasses are weakened and convex glasses strengthened by removing them further from the eyes, and *vice versa*.

The sides of the frame should touch the temples and pass behind the ears in all spectacles made for children, and preferably in every case where the glasses are to be worn always. The portion behind the ear should fit comfortably, so that the wearer is hardly conscious of it.

Under no circumstances should anyone but an emmetropic presbyope be allowed to wear folders. Folders never fit, are rarely correctly centred, and tend to become bent, so that one or both glasses are oblique

to the plane of the eyes, and one is often nearer the eye than the other.

A cylindrical lens becomes more cylindrical, and a spherical one sphero-cylindrical, by being placed obliquely before the eyes.

Pince-nez should be rigid and light. If they are worn always, they should, preferably, be frameless. The clips which keep pince-nez in position on the nose should be made of malleable material, so that they can be shaped to the sides of the nose, and the surface next the nose should be rough. It is most important that all glasses should "sit" horizontally; especially is this the case when cylinders are worn.

Monocles may be allowed in cases of monocular amblyopia (see page 157).

Children should always have spectacles, and not pince-nez, and the frames ought to be strong and light.

Crookes's Glass.—As far as we know the infra-red rays are of no use to us for visual purposes, but, bearing in mind the possibility that their continued action may be harmful to the eye, it is advisable, in selecting an anti-glare glass, to choose one that cuts off the infra-red rays, but *not* at the expense of the all-important screening off of the ultra-violet ones. At the same time, if such a glass has a slight neutral tint a small amount of luminosity is cut off and renders it more useful against glare.

After an enormous number of experiments extending over some years, Sir William Crookes has succeeded in finding such a glass, or, rather, many such glasses. Messrs. Chance Bros. have put on the market two glasses, Crookes "A" and Crookes "B."

Crookes "A" is practically No. 187, and its composition is:

Fused soda flux	83·0
Cerium nitrate, crystallised	17·0

But as it is difficult commercially to get a pure cerium salt, there is present a small amount of didymium, which gives the glass a pale pink tint when viewed edgeways. This glass cuts off 27 per cent. of the heat rays, practically all the ultra-violet rays (the limit being λ 3650), and transmits 99 per cent. of the light, and is of the greatest value in refraction work, especially in the correction of myopia, and the extra cost above ordinary glass is trifling.

Crookes "B" has a slightly darker tint, and corresponds to No. 197. Its composition is:

Fused soda flux	79·00
Cerium nitrate, crystallised	20·50
Nickel sulphate, crystallised	0·30
Cobalt sulphate, crystallised	0·05
Uranoso-uranic oxide	0·15
	100·00

It is opaque to ultra-violet rays of shorter wave length than λ 3700, and cuts off 41 per cent. of heat rays. It is transparent to 45 per cent. incident light.

It is not to be recommended for general use, but is especially indicated when very great glare or heat is encountered.

It is sometimes very useful in high myopia.

Final Note.—Patients ought always to be reminded that the treatment of their error of refraction is by no means permanent. Changes will take place. Young patients should be re-examined at least once a year (see page 98), older ones every two or three years.

CHAPTER XVIII

ILLUSTRATIVE CASES

Simple Hyperopia and Anisometropia.—Miss L., aged 21, complained of headaches, especially after doing any near work.

$$V. = \tfrac{6}{6} + \cdot 50 \text{ Hm. B.E.}$$

Under *atropine :*

R.V. $\tfrac{6}{18} + 1 \cdot 75 = \tfrac{6}{6}$. L.V. $\tfrac{6}{12} + 1 \cdot 50 = \tfrac{6}{6}$.

No astigmatism.

Ordered $+ \cdot 75$ sph. $+ \cdot 50$ sph.

To be worn *especially* when doing near work.

Her headaches disappeared.

Simple hyperopia without astigmatism or anisometropia rarely gives rise to symptoms in young people unless the error is great.

Simple Myopia—Heterophoria.—Mr. S., aged 25, clerk. Suffers from chronic conjunctivitis, which has been getting worse lately. Has worn glasses for distance, but never for near work.

$$V. = < \tfrac{6}{60} - 3 \cdot 5 = \tfrac{6}{6} \text{ B.E.}$$

His accommodation near point is 9 cms.

$$\begin{aligned} \therefore \text{a} &= \tfrac{100}{9} - 3 \cdot 5 \\ &= 11 - 3 \cdot 5 \\ &= 7 \cdot 5 \end{aligned}$$

His convergence near point is 18 cms. He has 1 m.a. latent divergence for distance, and 1·5 m.a. for $\tfrac{1}{4}$ metre (Maddox).

$$\begin{aligned} \therefore \text{ca} &= \tfrac{100}{18} - (-1) \\ &= 5 \cdot 5 + 1 \\ &= 6 \cdot 5 \text{ m.a.} \end{aligned}$$

He was ordered $- 3 \cdot 5$ B.E., to be worn always, and he was specially instructed never to approach his work nearer than 33 cms. Some months later he returned, showing great improvement. There was no heterophoria for distance, and only ·5 m.a. for $\tfrac{1}{4}$ metre.

Hyperopic Astigmatism—Epilepsy.—Master A. B., aged 10, has had epileptic attacks for some years, with only slight benefit from medical treatment.

$$\text{V.} = \tfrac{6}{6} \text{ in both eyes.}$$

Under *atropine* :

$$\text{R.E.}\left\{\begin{array}{l} + \cdot 25 \text{ cyl. (axis vert.)} \\ + 1 \text{ sph.} \end{array}\right\} = \tfrac{6}{6}.$$

$$\text{L.E.}\left\{\begin{array}{l} + \cdot 50 \text{ cyl. (axis vert.)} \\ + 1 \text{ sph.} \end{array}\right\} = \tfrac{6}{6}.$$

The cylinders were ordered for constant use. A report, received eight months later, stated that the boy had been perfectly well since wearing the glasses.

Hyperopic Astigmatism (Low).—Miss N., aged 24, has of late been suffering intensely from headaches, always aggravated by near work.

$$\text{V.} = \tfrac{6}{6} \text{ B.E.} \quad \text{No Hm.}$$

Under *homatropine* :

$$\text{V.} = \tfrac{6}{12}\left\{\begin{array}{l} + \cdot 25 \text{ cyl. (axis vert.)} \\ + \cdot 50 \text{ sph.} \end{array}\right\} = \tfrac{6}{5} \text{ B.E.}$$

The ophthalmometer shows ·25 direct astigmatism.

$$\text{Ordered } + \cdot 25 \text{ cyl. (axis vert.).} \quad \text{B.E.}$$

for constant use.

The wearing of this correction completely cured the patient.

Hypermetropic Astigmatism (Very Low)—Anisometropia—Eye-strain.— Private S., suffering from shell-shock, aged 22. Great lassitude; thoroughly ill—headache, insomnia, no organic lesion.

$$\text{V.} = \tfrac{6}{5} \text{ in both eyes.}$$

Under *atropine* :

$$\text{R.V.} = \tfrac{6}{12}\left\{\begin{array}{l} + \cdot 12 \text{ cyl. } \uparrow \\ + \cdot 62 \text{ sph.} \end{array}\right\} \tfrac{6}{6}. \qquad \text{L.V.}\left\{\begin{array}{l} + \cdot 25 \text{ cyl. } \overset{10}{\setminus} = \\ + \cdot 50 \text{ sph.} \end{array}\right\} \tfrac{6}{6}.$$

The following glasses were ordered *for constant use :*

$$\text{R.E.}\left\{\begin{array}{l} + \cdot 12 \text{ cyl. (axis vert.)} \\ + \cdot 12 \text{ sph.} \end{array}\right. \qquad \text{L.E.} + \cdot 25 \text{ cyl. } \overset{10}{\setminus}$$

and in a few weeks he was quite well.

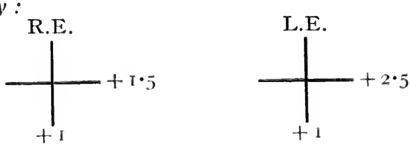
Astigmatism—Anisometropia.—Miss B., aged 30, complains of "dreadful headache" and insomnia.

$$\text{R.V. } \tfrac{6}{6}. \qquad \text{L.V. } \tfrac{6}{9}.$$

Under *homatropine* the ophthalmometer showed:

R.E. ·5 direct astigmatism.
L.E. 1·5 direct astigmatism.

Retinoscopy :



R.V. $\frac{6}{12}$ + ·5 cyl. (axis vert.) = $\frac{6}{6}$.
L.V. $\frac{6}{18}$ + 1·25 cyl. (axis vert.) = $\frac{6}{9}$.

The following glasses were ordered:

For constant use :

$$\text{R.E.}\begin{cases} +\cdot 5 \text{ cyl. (axis vert.)} \\ -\cdot 50 \text{ sph.} \end{cases}$$

$$\text{L.E.}\begin{cases} +1\cdot 25 \text{ cyl. (axis vert.)} \\ -\cdot 75 \text{ sph.} \end{cases}$$

Note.—On returning for the final examination when the effects of the cycloplegic had passed off, it was found that the patient preferred ·75 off the left and only ·50 off the right. When possible, it is always best to take a little more off the stronger glass, with the view of lessening the difference in the correction of the two eyes, at least in *one* meridian.

Simple Myopic Astigmatism.—Mr. P., aged 29. Has had migraine for some time.

V. = $\frac{6}{6}$ B.E.

Under *homatropine :* ophthalmometer shows ·5 direct astigmatism, and vision = $\frac{6}{6}$ $\bar{c}$ − ·5 cyl. (axis horizontal) B.E. On recovering from the cycloplegic, − ·25 sph. added to the cyl. improved each eye separately, but binocularly the *cyl. only* gave him $\frac{6}{6}$, and these glasses were ordered for constant use, and some weeks afterwards the patient reported that the migraine had disappeared.

Myopic Astigmatism (Very Low).—Miss N. B., aged 30, has suffered for some years from "nerves," and is now complaining of dyspepsia. Vision in both eyes was $\frac{6}{9}$ part, and the ophthalmometer showed inverse astigmatism ·12 in both eyes.

Under *homatropine :*

$$\tfrac{6}{12}\left\{\begin{matrix} -\cdot 12 \text{ cyl. (axis vert.)} \\ +\cdot 50 \text{ sph.} \end{matrix}\right\} = \tfrac{6}{6} \text{ B.E.}$$

The minus cylinder was given her to wear always, and six months later she reported that she was perfectly well and the dyspepsia had entirely disappeared.

Myopic Astigmatism (Compound).—Miss B., aged 28. Has never worn glasses. Complains of dreadful headaches.

V. = < $\frac{6}{60}$ and − 4 = $\frac{6}{12}$ B.E.

Under *homatropine* the ophthalmometer showed:

R.E. 1 inverse astigmatism.
L.E. ·5 inverse astigmatism.

$$\text{R.V.}\left\{\begin{array}{l} -1 \text{ cyl. (axis vert.)} \\ -3 \text{ sph.} \end{array}\right\} = \tfrac{6}{9}.$$

$$\text{L.V.}\left\{\begin{array}{l} -\cdot 5 \text{ cyl. (axis vert.)} \\ -3\cdot 5 \text{ sph.} \end{array}\right\} = \tfrac{6}{9}.$$

These glasses were ordered for constant use, and the patient reported that the headaches disappeared.

Note.—The above is also an example of *anisometropia*, and it is very commonly found in those cases, as above, where the difference is *not* great, that in one axis the refraction is the same in both eyes. Here the horizontal meridian is -4 in both eyes.

Mixed Astigmatism.—Miss H., aged 23, complains that her vision is very bad, and that the eyes are very painful. Never worn glasses.

$$\text{V.} = \tfrac{6}{24} \text{ in both eyes.}$$

Under *homatropine* the ophthalmometer showed 2·5 astigmatism oblique in both eyes.

Retinoscopy:

$$\text{R.V.}\left\{\begin{array}{l} +2\cdot 5 \text{ cyl. } 45 \\ -1\cdot 5 \text{ sph.} \end{array}\right\} = \tfrac{6}{12}.$$

$$\text{L.V.}\left\{\begin{array}{l} +3 \text{ cyl. } 40 \\ -2 \text{ sph.} \end{array}\right\} = \tfrac{6}{18}.$$

These glasses were ordered for constant use.

In cases of which above is an example visual acuity is generally poor, but great improvement results a few months after wearing the correction.

Mixed Astigmatism (Low) and Anisometropia and Eyestrain.—Miss T. P., aged 18, had had headaches and spinal pain for four years.

$$\text{R. and L.V.} = \tfrac{6}{6}.$$

Under *atropine:*

$$\text{R.V. } \tfrac{6}{12} \left\{\begin{array}{l} +\cdot 37 \text{ (axis vert.)} \\ +\cdot 12 \text{ sph.} \end{array}\right\} = \tfrac{6}{6}.$$

$$\text{L.V. } \tfrac{6}{9} \text{ pt.}\left\{\begin{array}{l} +\cdot 25 \text{ (axis vert.)} \\ +\cdot 12 \text{ sph.} \end{array}\right\} = \tfrac{6}{6}.$$

The following glasses were ordered for constant use:

$$\text{R.V.}\left\{\begin{array}{l} +\cdot 37 \text{ cyl. (axis vert.).} \\ -\cdot 12 \text{ sph.} \end{array}\right. \qquad \text{L.V.}\left\{\begin{array}{l} +\cdot 25 \text{ cyl. (axis vert.).} \\ -\cdot 12 \text{ sph.} \end{array}\right.$$

She immediately began to improve, and when last heard of was feeling better every week.

Simple Presbyopia.—Mr. H., aged 53. He says his distant vision is good, but that the glasses he uses for near vision (+1) do not give him the help they did, and after reading a short time the print becomes confused, and he has to rest a short time before resuming reading.

$$V. = \tfrac{6}{6}. \quad \text{No Hm. B.E.}$$

He reads D=0·5 well c. +2 sph., and the ophthalmometer shows *no* astigmatism. +2 were ordered for all near work.

Simple Hyperopia and Presbyopia.—Mr. E., aged 58. Has a considerable amount of conjunctivitis, from which he has been suffering for a year. Is using +2·5 sph. B.E.

$$\begin{aligned} &\text{R.V. } \tfrac{6}{36} + 1{\cdot}25 = \tfrac{6}{6}. \\ &\text{L.V. } \tfrac{6}{60} + 1{\cdot}5 \;\; = \tfrac{6}{6}. \end{aligned}$$

The ophthalmometer shows no astigmatism. Reads D=0·5 well $\bar{c}$ + 4 sph.

He refused glasses for distance, and was ordered +4 sph. for all near work.

Note.—He preferred the same glass in both eyes.

Simple Myopia and Presbyopia.—Mr. O., aged 52.

$$\left.\begin{matrix}\text{R.V.}\\ \text{L.V.}\end{matrix}\right\} = \tfrac{6}{60} - 3 = \tfrac{6}{6}.$$

The ophthalmometer shows *no* astigmatism. Reads D=0·5 well $\bar{c}$ − 1·5 sph.

He was ordered the following glasses:

$$\left.\begin{matrix}-\ 3 \text{ for distance}\\ -\ 1{\cdot}5 \text{ for reading}\end{matrix}\right\}\text{as invisible bi-focals.}$$

The patient's muscle test was normal, and he had no symptom of eyestrain.

Hyperopic Astigmatism and Presbyopia.—Miss E., aged 52, complains of constant headache.

$$\text{R.V.} = \tfrac{6}{24}\left\{\begin{matrix} +{\cdot}75 \text{ cyl. (axis vert.)}\\ +\ 1{\cdot}5 \text{ sph.}\end{matrix}\right\} = \tfrac{6}{6}.$$

$$\text{L.V.} = \tfrac{6}{24}\left\{\begin{matrix} +{\cdot}75 \text{ cyl. } \overset{10}{\backslash} \\ +\ 1{\cdot}5 \text{ sph.}\end{matrix}\right\} = \tfrac{6}{9}.$$

The ophthalmometer shows astigmatism as under:

R.E. ·75 direct.
L.E. ·50 direct and oblique.

With +2·5 added to above she read D=0·5 well.

Bi-focal glasses ordered for constant use, with correction as above.

Some months later patient reported that the headaches had entirely disappeared.

Note.—It will be noticed that the ophthalmometer gave in the left eye a lower correction than that which the patient preferred. This constantly occurs in oblique astigmatism, and it is probably due to the presence of a slight amount of *static* lenticular astigmatism, which, of course, the ophthalmometer cannot recognize.

Myopic Astigmatism and Presbyopia.—Mr. B., aged 46, complains of twitching of the eyelids and a strained feeling about the eyes after reading.

$$\left.\begin{array}{c}\text{R.V.}\\ \text{and}\\ \text{L.V.}\end{array}\right\}\left.\begin{array}{l}-\cdot 75 \text{ cyl. (axis vert.)}\\ -\cdot 75 \text{ sph.}\end{array}\right\} = \tfrac{6}{5}.$$

The ophthalmometer showed inverse astigmatism ·75. He reads easily D = 0·5 with + ·75 cyl. (axis horizontal).

The following glasses were ordered:

Distance :

$$\text{B.E.}\left\{\begin{array}{l}-\cdot 75 \text{ cyl. (axis vert.)}\\ -\cdot 75 \text{ sph.}\end{array}\right.$$

Reading :

B.E. + ·75 cyl. (axis horiz.).

He preferred to have two pairs of glasses, and *not* bi-focals.

Spasm of Accommodation.—Master L., aged 14. Has had some trouble with the eyes for some time, with headache after near work. He saw an optician, who tested his vision (without atropine), and the boy chose − 3 sph., which were ordered him.

$$\left.\begin{array}{c}\text{R.V.}\\ \text{L.V.}\end{array}\right\} < \tfrac{6}{60} - 1 = \tfrac{6}{6}.$$

Under *atropine :*

$$\text{R.V.}\tfrac{6}{12}\left\{\begin{array}{l}+\cdot 25 \text{ cyl. (axis horiz.)}\\ +\cdot 50 \text{ sph.}\end{array}\right\} = \tfrac{6}{5}.$$

$$\text{L.V.}\tfrac{6}{12}\left\{\begin{array}{l}+\cdot 12 \text{ cyl. (axis horiz.)}\\ +\cdot 50 \text{ sph.}\end{array}\right\} = \tfrac{6}{5}.$$

The ophthalmometer showed ·25 inverse astigmatism for the R.E., and ·12 for left. The cylinders were ordered for constant use, and in a few weeks the spasm entirely disappeared.

Note.—This case shows the danger of giving glasses, especially concave glasses, to young people, without using a cycloplegic. The eyestrain had produced spasm of the ciliary muscle, which masked the real condition, and made him appear to be myopic.

High Myopia (with Astigmatism) (Progressive ?).—Miss B., aged 17. Has been wearing for some time the following glasses:

$$\left.\begin{array}{l}-2 \text{ cyl. (axis horiz.)}\\ -10 \text{ sph.}\end{array}\right\} \text{B.E.}$$

Originally these helped her considerably in distant vision, but now they are only useful when reading, and even when using the glasses she holds her book 12 cms. from the eyes.

Under *atropine :*

$$\text{R.V.}\left\{\begin{array}{l}-1\cdot5\text{ cyl. }^{10}\\-18\text{ sph.}\end{array}\right\}=\tfrac{6}{12}\text{ one letter.}$$

$$\text{L.V.}\left\{\begin{array}{l}-2\cdot5\text{ cyl. }^{2}\\-15\text{ sph.}\end{array}\right\}=\tfrac{6}{12}\text{ one letter.}$$

The ophthalmometer shows:

R.E. 1·5 astigmatism, direct and oblique.
L.E. 2·0 astigmatism, direct and oblique.

Retinoscopy :

The atropine correction was ordered for *constant* use, and the patient was strictly enjoined never to approach her work nearer than 33 cms.

Considering the high myopia, the fundus of both eyes was fairly normal, although marked crescents were present. Three years later with the same glasses she read the whole of $\frac{6}{12}$ and D = 0·5 well at 33 cms. The eyes were again put under atropine, and the refraction was found to be practically the same as at the first examination.

Note.—This case is a marked example of the importance of preventing undue convergence in high myopia, and also illustrates the admirable result of fully correcting the error.

Aphakia.—Mrs. F., aged 58. Right eye: Advanced cataract. Projection good. Left eye: Commencing cataract; vision = $\frac{6}{12}$. Right cataract extracted, and five months later, after needling, vision was:

$$\left.\begin{array}{l}+13\text{ sph.}\\+2\text{ cyl. }^{45}\end{array}\right\}=\tfrac{6}{9}.$$

These glasses were ordered to be used for a short time every day, and later on, when the cataract in the left eye had advanced, + 3 was added for reading and the glasses ordered to be worn as bi-focals.

Myopic Astigmatism—Esophoria.—Master S. C., aged 14. Vision = $\frac{6}{6}$ in both eyes. Under atropine vision was:

$$\text{R.V. }\tfrac{6}{12}\text{ part}\left\{\begin{array}{l}-\cdot50\text{ cyl. (axis vert.)}\\+\cdot25\text{ sph.}\end{array}\right\}=\tfrac{6}{6}.$$

$$\text{L.V. }\tfrac{6}{18}\text{ part }-\cdot75\text{ cyl. }^{5}=\tfrac{6}{6}.$$

The ophthalmometer showed ·5 inverse astigmatism in the right eye, and in the left ·75 inverse astigmatism, slightly oblique. The Maddox test showed 1·5 metre angles of esophoria. He had been wearing 4° base out in both eyes, with no good result, symptoms being headache and general malaise. The following glasses were ordered for *constant* use:

R.E. – ·50 cyl. (axis vert.).

L.E. – ·75 cyl. $\backslash\!\!/^{5}$

He had been in the habit of approaching his work very near to the eyes, and no doubt this produced a spasm of the internal recti, and the trouble had been kept up by eyestrain. He recovered completely in a few weeks.

Muscle Strain—Convergence "Insufficiency"—Myopia—Anisometropia.—F. L., aged 31, a clerk, suffering from slight chronic conjunctivitis, complains of headache, chiefly frontal, coming on after work; says that lately the headache appears before he has been two hours at work.

$$\text{V.} = \begin{cases} \text{R.} < \frac{6}{60} - 2\cdot5 \text{ D.} = \frac{6}{6}. \\ \text{L.} < \frac{6}{60} - 1 \text{ D.} \quad = \frac{6}{6}. \end{cases}$$

His convergence near point is 18 cms.; if he is told to look at the tip of a pen at this distance, and any attempt is made to bring it nearer, the right internal rectus is seen to suddenly give way, the right eye turns considerably outwards, and diplopia supervenes. Examined by the Maddox test, he shows $\frac{1}{2}$ m.a., latent divergence for distance, and 1 m.a., which soon becomes 2 m.a., for $\frac{1}{4}$ metre. He was given a mixture of iron and strychnine, and advised to take a fortnight's rest, and on returning at the end of that time the following great improvement was noted: c P = 8 cms. Latent divergence for distance = $\frac{1}{6}$ m.a., and at $\frac{1}{4}$ metre = $\frac{2}{3}$ m.a. His range of convergence had increased from 6 m.a. to 12 m.a. He was advised to return to business, and was ordered the above correction for constant use, and told not to approach his work nearer than 25 cms. He eventually became completely well.

Convergent Concomitant Strabismus.—Master E., aged 8. Has marked convergent strabismus, which is alternating, although he most frequently fixes with the left eye.

$$\left.\begin{matrix}\text{R.V.}\\ \text{L.V.}\end{matrix}\right\} = \tfrac{6}{5} + 1 = \text{Hm.}$$

Under atropine for a fortnight the squint entirely disappeared, and $+2 = \frac{6}{5}$ B.E. He was given + 1 sph. for both eyes for constant use in circular frames.

A year later the atropine correction was only 1·5, and + ·75 was ordered; eighteen months later the atropine correction was only + 1, and, as the squint had then entirely disappeared, glasses were discontinued.

CHAPTER XIX

VISION TESTS FOR THE SERVICES

I AM indebted to the heads of the various departments of the public services for their courtesy in supplying me with these revised standards.

COMMISSIONS IN THE REGULAR ARMY AND SPECIAL RESERVE.*

(*a*) Squint, or any morbid condition of the eyes or of the lids of either eye liable to the risk of aggravation or recurrence, will cause the rejection of the candidate.

(*b*) The examination for determining the acuteness of vision includes two tests: one for distant, the other for near, vision. The Army test-types will be used for the test for distant vision, without glasses, except where otherwise stated below, at a distance of 20 feet; and Snellen's Optotypi for the test for near vision, without glasses, at any distance selected by the candidate. Each eye will be examined separately, and the lids must be kept wide open during the test. The candidate must be able to read the tests without hesitation in ordinary daylight.

(*c*) The standards of the minimum acuteness of vision with which a candidate will be accepted are as follows:

STANDARD I.

	Right Eye.	*Left Eye.*
Distant vision:	V. $=\frac{6}{6}$.	V. $=\frac{6}{6}$.
Near vision:	Reads 0, 6.	Reads 0, 6.

STANDARD II.

	Better Eye.	*Worse Eye.*
Distant vision:	V. $=\frac{6}{6}$.	V., without glasses = not below $\frac{6}{60}$; and, after correction with glasses = not below $\frac{6}{24}$.
Near vision:	Reads 0, 6.	Reads 1.

* These regulations were received from the War Office in November, 1917.

STANDARD III.

	Better Eye.	*Worse Eye.*
Distant vision:	V., without glasses = not below $\frac{6}{24}$; and, after correction with glasses = not below $\frac{6}{6}$.	V., without glasses = not below $\frac{6}{24}$; and, after correction, with glasses = not below $\frac{6}{12}$.
Near vision:	Reads 0, 8.	Reads 1.

(*d*) In Standard III., the standard for the test for distant vision, without glasses, for officers of the Special Reserve, will be not below $\frac{6}{36}$.

(*e*) Inability to distinguish the principal colours will not be regarded as a cause for rejection, but the fact will be noted in the proceedings and the candidate will be informed.

(*f*) The degree of acuteness of vision of all candidates for commissions will be entered in the proceedings in the following manner:

(i.) Candidates whose vision fulfils the requirements of Standard I.:

"Vision, normal."

(ii.) Candidates whose vision does not fulfil the requirements of Standard I.:

V.R. = ... ; with glasses = ... ; Reads........
V.L. = ... ; with glasses = ... ; Reads........

(*g*) No relaxation of the standard of vision will be allowed.

ROYAL AIR SERVICE.

"Vision (including colour perception) must be normal."

NAVY (OFFICERS AND MEN).

To determine the acuity of vision, Snellen's letter types are to be used, and care is to be taken that the proper distances are carefully marked off, either on the floor or on the wall of the room. Should the room not be sufficiently long for the 6-metre card to be used, the 5-metre card may be substituted, and both these cards are to be supplied, as well as the proper size of types for testing near vision.

The colour sense is to be determined by means of Holmgren's wool-test, and care is to be taken that when the wools become dull from use they are to be renewed.

Officers.—A candidate must have *no* defect of sight; he must be able to read without glasses $\frac{6}{6}$ by each eye separately, and the near type at the distance for which it is marked. Squint, or any defective action of the eye muscles, any disease of the eye, or any imperfection in the colour sense, disqualifies.

Men :

Rating.	Vision Required.
Air Service	Vision, $\frac{6}{6}$ one eye, $\frac{6}{9}$ the other. Colour sense must be normal.
Wiremen, Armourer's Crew, and Shipwrights	*Long Service.*—Vision, $\frac{6}{9}$ both eyes. Colour sense must be normal. *Hostilities only.*—Vision, $\frac{6}{12}$ both eyes.
Blacksmiths, Coopers, Plumbers, and Painters	Vision, $\frac{6}{9}$ both eyes.
Boys	Vision, $\frac{6}{6}$ both eyes. Colour sense must be normal.
Carpenter's Crew	Vision, $\frac{6}{9}$ both eyes. Colour sense must be normal.
Electrical Artificers	*Long Service.*—Vision, $\frac{6}{9}$ both eyes. Colour sense must be normal. *Hostilities only.*—Vision, $\frac{6}{12}$ both eyes. Colour sense must be normal.
Engine-Room Artificers ..	Vision, $\frac{6}{9}$ one eye, $\frac{6}{12}$ the other. Colour sense must be normal.
Officers' Stewards and Cooks, Boy Servants, and Ships' Cooks	Colour sense not essential. Glasses allowed. Vision, $\frac{6}{12}$ both eyes.
Royal Marine Bands (Buglers, R.M.L.I., R.M.A., and Band Boys)	Vision for Buglers: $\frac{6}{6}$ one eye, $\frac{6}{12}$ the other. Colour sense must be normal. Vision for Band Boys: $\frac{6}{12}$ both eyes. Colour sense not essential.
Royal Marine Artillery ..	*Long Service.*—Vision, $\frac{6}{6}$ one eye, $\frac{6}{12}$ the other. Colour sense must be normal. *Hostilities only.*—Vision, $\frac{6}{24}$ both eyes. Colour sense not essential. Glasses allowed.
Royal Marine Light Infantry	*Long Service.*—Vision, $\frac{6}{6}$ one eye, $\frac{6}{12}$ the other. Colour sense must be normal. *Hostilities only.*—Vision, $\frac{6}{24}$ both eyes. Colour sense not essential. Glasses allowed.

Rating.	Vision Required.
Seamen	*Special Service.*—Vision, $\frac{6}{9}$ one eye, $\frac{6}{18}$ the other. Colour sense must be normal. *Hostilities only.*—Same standard.
Sick-Berth Attendants ..	Vision, $\frac{6}{12}$ both eyes. Colour sense must be normal. Glasses allowed.
Stokers	Vision, $\frac{6}{12}$ one eye, $\frac{6}{24}$ the other. Colour sense not essential.

Any defect of vision must be due to errors of refraction which can be corrected to normal by glasses, and vision without glasses must in any case be not less than $\frac{6}{60}$ with each eye, and the candidate must also be able to read D = 0, 6 of Snellen's test types.

Note.—For distant vision, D = $\frac{6}{6}$ is considered normal; for near vision, ability to read D = ·6 at any distance chosen by the candidate.

Assistant Clerkships in the Navy.—Short-sighted candidates, in other respects fit, are especially considered; a moderate degree of refraction error would not disqualify, provided the eyes are in other respects normal.

APPOINTMENTS UNDER THE GOVERNMENT OF INDIA.

The Ecclesiastical, Education, Geological Survey, Agricultural, Indian Finance, Customs, Civil Veterinary, and Other Departments not specially provided for in the following pages.

1. A candidate may be admitted into the Civil Services of the Government of India if ametropic in one or both eyes, provided that, with correcting lenses, the acuteness of vision be not less than $\frac{6}{9}$ in one eye and $\frac{6}{6}$ in the other; there being no morbid changes in the fundus of either eye.

2. Cases of myopia, however, with a posterior staphyloma, may be admitted into the Service, provided the ametropia in either eye does not exceed 2·5 D, and no active morbid changes of choroid or retina be present.

3. A candidate who has a defect of vision arising from nebula of the cornea is disqualified if the sight of either eye be less than $\frac{6}{12}$; and in such a case the acuteness of vision in the better eye must equal $\frac{6}{6}$, with or without glasses.

4. Squint or any morbid condition, subject to the risk of aggravation or recurrence, in either eye, may cause the rejection of a candidate. The existence of imperfection of colour sense will be noted on the candidate's papers.

*The Departments of Forest, Survey, Telegraph, Factories, and for Various Artificers.**

1. If myopia in one or both eyes exists, a candidate may be passed, provided the ametropia does not exceed 2·5 D, and if with correcting glasses, not exceeding 2·5 D, the acuteness of vision in one eye equals $\frac{6}{9}$ and in the other $\frac{6}{6}$, there being normal range of accommodation with the glasses.

2. Myopic astigmatism does not disqualify a candidate for service, provided the lens or the combined spherical and cylindrical lenses required to correct the error of refraction do not exceed – 2·5 D; the acuteness of vision in one eye, when corrected, being equal to $\frac{6}{6}$, and in the other eye $\frac{6}{9}$, together with normal range of accommodation with the correcting glasses, there being no evidence of progressive disease in the choroid or retina.

3. A candidate having total hypermetropia not exceeding 4 D is not disqualified, provided the sight in one eye (when under the influence of atropine) equals $\frac{6}{9}$, and in the other eye equals $\frac{6}{6}$, with + 4 D or any lower power.

4. Hypermetropic astigmatism does not disqualify a candidate for the Service, provided the lens or combined lenses required to cover the error of refraction do not exceed 4 D, and that the sight of one eye equals $\frac{6}{9}$, and of the other $\frac{6}{6}$, with or without such lens or lenses.

5. A candidate having a defect of vision arising from nebula of the cornea is disqualified if the sight of one eye be less than $\frac{6}{12}$. In such a case the better eye must be emmetropic. Defects of vision arising from pathological or other changes in the deeper structures of either eye which are not referred to in the above rules may exclude a candidate for admission into the Service.

6. Squint or any morbid condition, subject to the risk of aggravation or recurrence, in either eye, may cause the rejection of a candidate. The existence of imperfection of colour sense will be noted on the candidate's papers.

Public Works Department and Superior Establishments, Railway Department.

1. If myopia in one or both eyes exists, a candidate may be passed, provided the ametropia does not exceed 3·5 D, and if with correcting glasses not exceeding 3·5 D the acuteness of vision in one eye equals $\frac{6}{6}$, there being normal range of accommodation with the glasses.

2. Myopic astigmatism does not disqualify a candidate, provided the lens, or the combined spherical and cylindrical lenses, required to correct the error of refraction does not exceed 3·5 D; the acuteness of vision in one eye, when corrected, being equal to $\frac{6}{6}$, and in the other $\frac{6}{6}$, together with normal range of accommo-

* Artificers engaged in map and plan drawing may be considered separately, and this standard relaxed if it appears to be desirable.

dation with the correcting glasses, there being no evidence of progressive disease in the choroid or retina.

3. A candidate having total hypermetropia not exceeding 4 D is not disqualified, provided the sight in one eye (when under the influence of atropine) equals $\frac{6}{9}$, and in the other eye equals $\frac{6}{6}$, with +4 D glasses, or any lower power.

4. Hypermetropic astigmatism does not disqualify, provided the lens or combined lenses required to cover the error of refraction do not exceed 4 D, and that the sight of one eye equals $\frac{6}{9}$, and the other $\frac{6}{6}$, with or without such lens or lenses.

5. A candidate having a defect of vision arising from nebula of the cornea is disqualified if the sight of that eye be less than $\frac{6}{12}$. In such a case the better eye must be emmetropic. Defects of vision arising from pathological or other changes in the deeper structures of either eye which are not referred to in these rules may exclude a candidate.

6. Squint or any morbid condition, subject to the risk of aggravation or recurrence, in either eye, may cause the rejection of a candidate. Any imperfection of the colour sense is a disqualification for appointment to the Engineering Branch of the Railway Department, or as Assistant Superintendent in the Traffic Department. In all other cases a note as to any imperfection of colour sense will be made on the candidate's papers.

The Indian Medical Service and the Police Department.

1. Squint, or any morbid condition of the eyes or of the lids of either eye liable to the risk of aggravation or recurrence, will cause the rejection of the candidate.

2. The examination for determining the acuteness of vision includes two tests—one for distant, the other for near, vision. The army test-types will be used for the test for distant vision, without glasses, except where otherwise stated below, at a distance of 20 feet; and Snellen's Optotypi for the test for near vision, without glasses, at any distance selected by the candidate. Each eye will be examined separately, and the lids must be kept wide open during the test. The candidate must be able to read the tests without hesitation in ordinary daylight.

3. A candidate possessing acuteness of vision, according to one of the standards herein laid down, will not be rejected on account of an error of refraction, provided that the error of refraction, in the following cases, does not exceed the limits mentioned—viz.: (*a*) In the case of *myopia*, that the error of refraction does not exceed 2·5 D; (*b*) that any correction for *astigmatism* does not exceed 2·5 D; and, in the case of myopic astigmatism, that the total error of refraction does not exceed 2·5 D.

4. Subject to the foregoing conditions, the standards of the minimum acuteness of vision with which a candidate will be accepted are as follows:

Standard I.

Right Eye.	*Left Eye.*
Distant vision: V. $= \frac{6}{6}$.	V. $= \frac{6}{6}$.
Near vision: Reads 0, 6.	Reads 0, 6.

Standard II.

Better Eye.	*Worse Eye.*
Distant vision: V. $= \frac{6}{6}$.	V., without glasses = not below $\frac{6}{60}$; and, after correction with glasses = not below $\frac{6}{24}$.
Near vision: Reads 0, 6.	Reads 1.

Standard III.

Better Eye.	*Worse Eye.*
Distant vision: V., without glasses = not below $\frac{6}{24}$; and after correction with glasses = not below $\frac{6}{6}$.	V., without glasses = not below $\frac{6}{24}$; and, after correction with glasses = not below $\frac{6}{12}$.
Near vision: Reads 0, 8.	Reads 1.

N.B.—In all other respects candidates for these two branches of the Service must come up to the standard of physical requirements laid down for candidates for commissions in the army.

The Indian Pilot Service, and Candidates for Appointments as Guards, Engine-drivers, Signalmen, and Pointsmen on Railways.

1. A candidate is disqualified unless both eyes are emmetropic, his acuteness of vision and range of accommodation being perfect.
2. A candidate is disqualified by any imperfection of his colour sense.
3. Strabismus, or any defective action of the exterior muscles of the eyeball, disqualifies a candidate for these branches of service.

The Indian Marine Service, including Engineers and Firemen.

1. A candidate is disqualified if he has an error of refraction in one or both eyes which is not neutralized by a concave or by a convex 1 D lens, or some lower power.
2. A candidate is disqualified by any imperfection of his colour sense.
3. Strabismus, or any defective action of the exterior muscles of the eyeball, disqualifies a candidate for this branch of service.

Special Duty.

Candidates for special duty under Government must possess such an amount of acuteness of vision as will, without hindrance, enable them to perform the work of their office for the period their appointment may last. In all cases of imperfection of colour sense a note will be made on the candidate's papers.

HOME CIVIL SERVICE.

There is no fixed standard. The candidate is referred to "a competent medical adviser," leaving him to apply whatever tests he may deem suitable, and whatever standard the particular situation may require.

A candidate is considered unfit if he has any serious defect in vision. A moderate degree of ordinary short sight corrected by glasses would not, as a rule, be regarded as a disqualification; but candidates for the Customs Outdoor Service are liable to disqualification for any defect of vision. Candidates for some other appointments of a special character would be rejected for colour blindness, but for the Covenanted Civil Service of India and for ordinary home appointments it is not by itself a disqualification.

PRISON SERVICE.

Candidates are expected to have "normal vision" in both eyes, and any slight departure from normal vision is considered on its merits in accordance with the duties which the candidate would be required to perform if appointed.

THE METROPOLITAN POLICE SERVICE.

Candidates are required to have "normal vision" in both eyes, without glasses. The ordinary test-types are used, and the range of accommodation is sometimes, but not uniformly, tested. Candidates who show only slight deviation from the "normal" standard are considered on their merits.

ENGLISH RAILWAYS.

No uniform standard. Each company has its own standard.

Every engine-driver should have normal colour perception; and, without glasses, vision should be at least $\frac{6}{12}$ in each eye.

TABLE SHOWING THE VISUAL STANDARDS FOR RECRUITS IN THE CHIEF EUROPEAN ARMIES. (PATERSON AND TRAQUAIR.)

	Amount of Short Sight (Myopia) Allowed.		Standard of Corrected Vision.		Remarks.
	Combatants.	Non-combatants.	Combatants.	Non-combatants.	
GERMANY	6·5 D. For Landsturm no limit if standard of corrected vision attained.	—	$\frac{1}{2}$ in better eye. Other eye may have minimal vision. For Landsturm vision $=\frac{1}{4}$. If one eye has vision $=\frac{1}{2}$ the other may be blind.	—	Vision with glasses (corrected vision) counts.
AUSTRIA..	6 D.	Above 6 D. no limit if standard of corrected vision is attained.	Group 1, $\frac{1}{2}$ in each eye. Group 2, $\frac{1}{2}$ in one; $\frac{1}{4}$ in other.	$\frac{1}{4}$ in one eye; $\frac{1}{10}$ in the other.	Vision with glasses counts.
FRANCE ..	7 D.	Above 7 D. no limit if standard of corrected vision is attained.	$\frac{1}{2}$ in one eye; $\frac{1}{20}$ in the other.	$\frac{1}{4}$ in one eye; $\frac{1}{20}$ in the other.	Vision with glasses counts.
ITALY ..	7 D.	—	$\frac{1}{3}$ in each eye, or $\frac{1}{12}$ in one eye if the other has $\frac{1}{1}$ (full vision).		Vision with glasses counts.
GREAT BRITAIN*	No amount specified, but according to vision required highest amount possible is about 2·5 D.	No amount specified, but according to vision required highest amount possible is about 2·5 D. in better eye and 3·5 D. in worse eye.	No correction allowed for general service. Uncorrected vision must be $\frac{1}{4}$ in each eye, or $\frac{1}{4}$ in the right eye with $\frac{1}{10}$ in the left.	Uncorrected vision must be $\frac{1}{4}$ in better eye, $\frac{1}{10}$ in worse eye. The better eye may be the left.	Vision without glasses counts. For home service, garrison service, and garrison service abroad, glasses are allowed within unspecified limits.

* These standards do not apply to the conscripted army.

BIBLIOGRAPHY

I have to acknowledge my indebtedness to the following books and papers for much valuable material:

"Accommodation and Refraction of the Eye": Donders.
"The Refraction and Accommodation of the Eye": Landolt.
"Refraction of the Eye": Hartridge.
"Refraction and how to Refract": Thorington.
"The Eye, its Refraction and Diseases": Gibbons.
"Refraction": Druiff.
"Kurzsichtigkeit": Hirshberg.
"Anomalies de la Refraction": Fromaget and Bichelonne.
"Squint": Worth.
"Convergent Strabismus": Holthouse.
"The Ocular Muscles": Maddox. 2nd edition.
"Ophthalmological Prisms": Maddox.
"Prismatic Combinations": Percival.
"Prescribing of Spectacles": Percival.
"Examination of the Eye": Snell.
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"Headaches": Day.

Transactions of the Ophthalmological Society.
The Ophthalmoscope.
The Ophthalmic Review.
British Journal of Ophthalmology.
Graefe's Archiv f. Ophthalmologie.
Knapp's Archives of Ophthalmology.
Transactions of the American Ophthalmological Society.
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Annals d'Oculistique.

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